VISIT…

SECTION 26

PUMPS

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Pumps... Major Classes and Types

One of man's oldest aids, the pump today ranks second only to the electric motor as the most widely used industrial machine. Anything that will flow is pumped–from highly volatile ether to thick muds and sludges. moltem metals and liquids at 1000 F, or higher, pose few real problems for modern pumps.

Though the origin of pumps is lost in antiquity, we do know that crude pumping devices provided water for ancient Egypt, China, India, Greece and Rome. Today the U.S. alone draws more than 200 billion gallons each day from its water resources and pumps move almost every drop. Of this total, an impressive 80 billion gallons is said to be industry's share.

To meet these demands we find an almost confusingly large variety of available pumps. They range from tiny adjustable displacement units to giants handling well over 100,000 gallons per minute. Number of designs soars into the hundreds, some differing in elements as small as packing glands, some in the entire principle of operation.

It's neither possible nor desirable to cover every variation in a concise practice practical handbook or manual. So we've made a highly selective choice of widely used industrial pumps of all classes and types – the pumps you're likely to run into in your work. And we've stuck to units using mechanical means to move liquid from one point to another, putting aside for a time such devices as ejectors, hydraulic rams, etc.

So you'll find the important facts about industrial pumping in easy-to-read form in the following pages. Put them to work improving the effectiveness of your pumping operations.

CLASS	TYPE	IMPORTANT GENERAL FACTS
CENTRIFUGAL	Volute	The majority of centrifugal pumps built in the U.S. today are volute type. They are available as horizontal or vertical pumps, single- or multistage for wide flow ranges
	Diffuser	Diffuser-type centrifugals find many uses as multistage high-pressure units. Originally more efficient than volute-type pumps, today efficiency of both types is about equal
	Mixed-flow	Mixed-flow centrifugal pumps are ideal for low-head large-capacity applications. Usually vertical, they have a single-inlet impeller. Some horizontal units are built
	Axial-flow	Axial-flow units, often called propeller pumps, develop most of their head by lifting action of vanes, are usually vertical, and best suited for low heads, large capacities
	Turbine or regenerative	For clear liquids, turbine pumps, either horizontal or vertical, fill a need between other centrifugal and usual rotary designs. They are low- to medium-capacity, high-head
ROTARY	Gear Vane	Gear pumps consist of two or more gears (spur, single- or double-helical teeth), while vane pumps have a series of vanes, blades or buckets turned by a single rotor. This rotary class also includes lobe or shuttle-block designs
	Cam-and-piston Screw	Cam-and-piston rotaries, like most types in this class, are positive-displacement units, giving steady discharge flow. Along with screw-type pumps, and related designs, they handle a wide range of nonabrasive viscous liquids
RECIPROCATING	Direct-acting	Old standbys for years, direct-acting steam pumps now are available in many designs for handling cold or hot water, oil, and a wide range of industrial liquids of many types
	Power	Power pumps are driven from outside through a crankshaft or other device. Capacities range from very low to medium flows, at pressures up to 15,000 psi, or higher
	Crank-flywheel	Crank-and-flywheel pumps are one form of reciprocating power pump, so designated to distinguish them from power pumps using, for example, an eccentric as drive mechanism

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classes and types in use today

	Centrifugal		Rotary	Reciprocating		
	Volute and diffuser	Axial flow	Screw and gear	Direct-acting steam	Double-acting power	Triplex
Discharge flow	Steady	Steady	Steady	Pulsating	Pulsating	Pulsating
Usual max. suction lift, ft	15	15	22	22	22	22
Liquids handled	Clean, clear; dirty, abrasive; liquids with high solids content		Viscous, nonabrasive	Clean and clear		
Discharge pressure range	Low to high		Medium	Low to highest produced		
Usual capacity range	Small to largest available		Small to medium	Relatively small		
How increased head affects:						
Capacity	Decrease		None	Decrease	None	None
Power input	Depends on specific speed		Increase	Increase	Increase	Increase
How decreased head affects:						
Capacity	Increase		None	Small increase	None	None
Power input	Depends on specific speed		Decrease	Decrease	Decrease	Decrease

DEFINITIONS

PUMPING is the addition of energy to a liquid to *move it from one point to another*

CENTRIFUGAL PUMPS employ centrifugal force to develop a pressure rise for moving a liquid

ROTARY PUMPS use gears, vanes, pistons, screws, cams, segments, etc, in a fixed casing to produce steady positive displacement of a liquid

RECIPROCATING PUMPS use pistons, plungers, diaphragms or other devices to positively displace a given volume of liquid during each stroke of the unit

IMPELLER is the rotating element in a centrifugal pump through which liquid passes and by means of which energy is imparted to the liquid

CASING of a centrifugal pump is the housing surrounding the impeller. It contains the bearings for supporting the shaft on which impeller mounts

LIQUID PISTON OR PLUNGER of a reciprocating pump is the moving member that contacts the liquid and imparts energy to it

SINGLE-STAGE centrifugal pump is one in which total head is developed by one impeller

MULTISTAGE centrifugal pump is one having two or more impellers acting in series in one casing

Pumps . . . major classes and types

The world of pumps can be extremely confusing to newcomers—and even to some oldtimers. Diagram, *left*, is designed to clear up much of the mystery and confusion surrounding pump *classes* and *types*. You might call it your road map to the world of pumps. Based on often-used standard classifications, it incorporates a number of useful facts that are a big help in pump selection and application.

Three classes of pumps find use today—*centrifugal, rotary* and *reciprocating*. Note that these terms apply only to the mechanics of moving the fluid, not to the service for which the pump is designed. This is important, because many pumps are built and sold for a specific service, and in the complex problem of finding which has the best design details we may overlook the basic problems of class and type.

Each classification is further subdivided into a number of different types, diagram *left*. For example, under the rotary classification we have cam, screw, gear and vane pumps. Each is a particular type of rotary pump.

To go one step further, let's take a brief look at a fuel-oil pump in wide use today. It is a rotary three-screw type available with rotors of a number of different materials and four means of balancing axial thrust.

The last two items are important *details* in pump application; first two are keys to classification of the unit. The Hydraulic Institute recommends that the standard classification be considered as applying to type only, leaving the builder to use the details he has developed or standardized for that type of pump. So in selecting a pump we often find we must compare, detail for detail, a number of makes. Broad breakdown in diagram comes in handy then.

Our next consideration is a wide statement of the general characteristics of a given class of pumps. Table, *above left*, does just this for us.

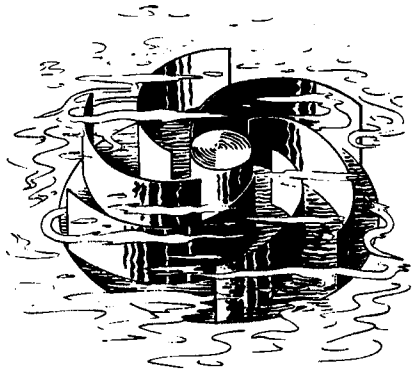
For example, if we want to handle relatively small capacities of clean, clear liquids at high head, we can refer to the table. In any problem of this type we must remember that suction lift should not exceed recommended limit. Capacity in gallons per minute (gpm) determines pump size and influences classification. Nature of fluid is also involved, as is pump construction. Head is a big factor.

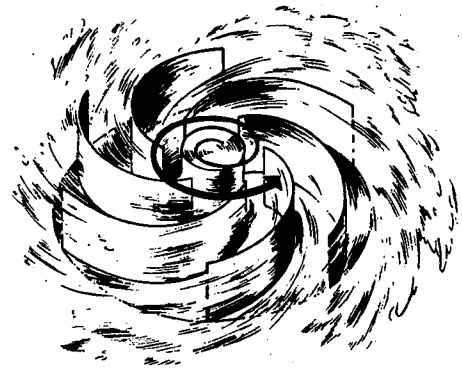
Table shows a reciprocating pump is suitable for the general conditions we have in mind—small capacity, high head, clean, clear liquids. Then, depending on job needs, we may choose a piston or plunger type, direct-acting, crank-and-flywheel, or power type. It may be simplex, duplex, triplex, or have a larger number of cylinders.

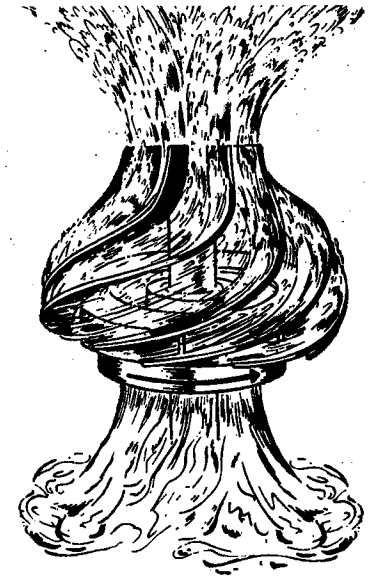
Once we've settled these items we're ready to study valve details, materials, drives, etc. In general, you'll find that pump details are greatly influenced by job requirements. Thus the particular arrangement of a centrifugal pump may depend as much on piping, space and working conditions as on any other existing factors. Drive chosen for the pump may be fixed by the pump speed, plant heat balance, power supply available or cost of a particular fuel in the area. But again, these are details, to be decided after we find a pump suitable for the hydraulic conditions we must meet. And the key to meeting the hydraulic conditions is the right class and type of pump.

Where two or more different units meet hydraulic needs, we must go one step further and decide which pump is best for the installation. We may want or need low first cost, long life or maximum operating economy. Normally we do not find all in one package. So we must decide which is most important and go ahead from there.

Getting the right pump is much like coming to a fork in the road. Our map tells us which way to turn. Once on the right road all we need do is watch our route markers. The next 29 pages do just that for you in the world of pumps.







CENTRIFUGAL

As a boy you probably whirled around your head a bucket on the end of a rope, just like the little guy in the three sketches above. As you recall, the water stayed in the bucket just as long as you kept it turning at a fair speed. The force that kept the water in the bucket is at work in centrifugal pumps.

Imagine an impeller at rest in water, *above left.* This is like the lad's bucket before he starts whirling it. Now rotate the impeller, *middle sketch.* Water will fly out from between the blades just as it would squirt out of the whirling bucket if it had a hole in the bottom.

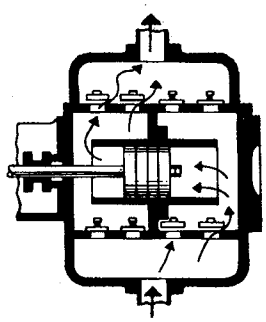
The force causing the water to leave the impeller (or the bucket) is *centrifugal force* and that's where pumps of this class get their name. They depend on centrifugal action even though details differ, as we'll see later.

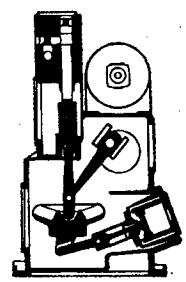
Going back to the middle sketch, as the impeller throws out liquid, more rushes into the center where the lowest pressure exists, and where a suction pipe is normally fitted. This liquid too is thrown out, is followed by more, and we have the steady discharge characteristic of centrifugals.

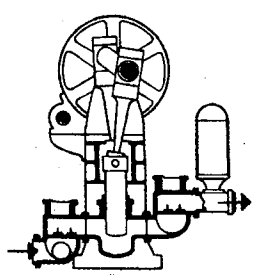
Once the liquid is being thrown from the impeller we must guide it to its destination. Otherwise we've accomplished little more than make a big splash.

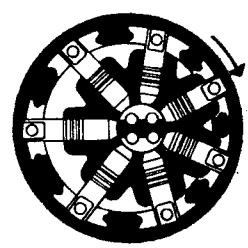
By putting the impeller in a casing we can change flow from haphazardly outward to controlled movement in the direction we want. With vanes like those of the deepwell pump in the righthand sketch we can even turn the flow upward. A casing, with or without vanes, acts something like a hose attached to the bottom of the boy's bucket.

The result is a workable pump for imparting energy to a liquid at one point to cause it to move to another.









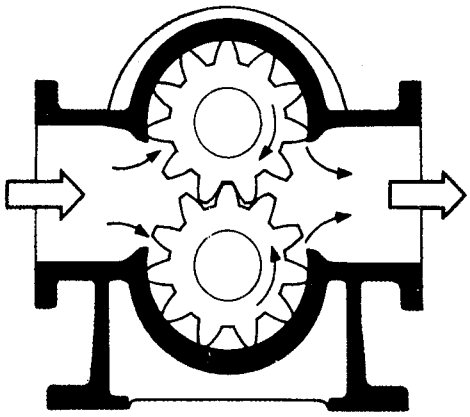
RECIPROCATING

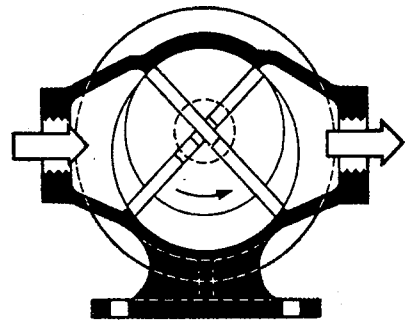
Long of major importance in the pumping field, reciprocating units today are finding many new uses, particularly in the fields of metering and proportioning, and where extremely high pressures are needed.

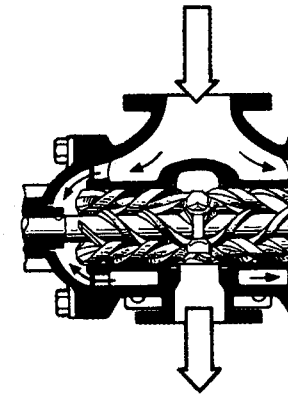
Direct-acting steam pumps, *top left,* have two sets of valves in the liquid end. When the piston moves to the left as shown, liquid is drawn in through the righthand set of suction valves and liquid previously drawn into the cylinder is discharged through the upper left set of discharge valves. This is a double-acting pump, liquid being discharged on every stroke. The actual arrangement of the valves differs in various designs.

Power pumps, *top right and lower left,* have a number of different arrangements for suction and discharge valves. In these two single-acting units, liquid is drawn into the cylinder during one stroke of the plunger. On the next stroke, the plunger forces liquid through the discharge valves into the pump outlet.

Radial-piston pumps, *lower right,* one of many relatively recent designs, have their pistons attached to an outer ring whose center of rotation can be changed. Moving the ring to an eccentric position produces suction and discharge through valves in the center of the pump. Reversing the direction of ring rotation reverses liquid flow. A large number of other designs are discussed later.







ROTARY Like reciprocating pumps but unlike centrifugals, most rotary pumps are positive-displacement units — that is a given quantity of liquid is discharged for each revolution of the shaft. Like the centrifugal pump, flow is usually steady, without large pressure pulsations.

Rotary gear pumps, *above left,* have two or more gears in a casing and during rotation the liquid fills the spaces between the gear teeth on the suction side. From there it is carried around and squeezed out as the teeth mesh on the other side of the pump.

Sliding-vane rotary pumps, *above center,* are built in a number of different designs. In the type shown, the vanes move in and out of the rotor, which is set off-center in the casing. When the rotor turns counterclockwise, liquid flows into the cavity formed by rotor bottom and casing wall.

As the rotor turns, it brings the next vane into position to trap the liquid in the cavity. Further rotation forces the liquid around and out the discharge opening of the pump. The vanes are held against the inner wall of the casing by centrifugal force produced by rapid rotation of the rotor.

Screw pumps, *above right,* draw the liquid into one or both ends of the rotor or rotors, where it is trapped in the pockets formed by the threads. It is moved along to the discharge point much like a nut on a thread. Screw-type rotary pumps may have one, two or three screws. When only a single screw is used, liquid enters at one end, is discharged at the other. The screw runs in a double-threaded helix. Clearance is an important factor in many rotary-pump designs that are used today.

Later, pp 88, we'll discuss the large number of other rotary-pump designs used for a variety of industrial services.

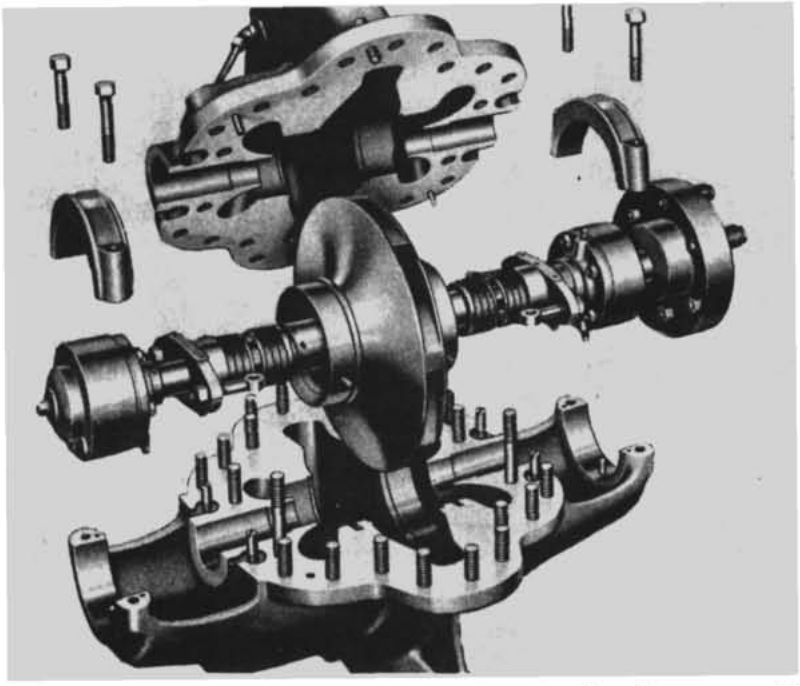
How pumps work

OTHER PUMPING PRINCIPLES

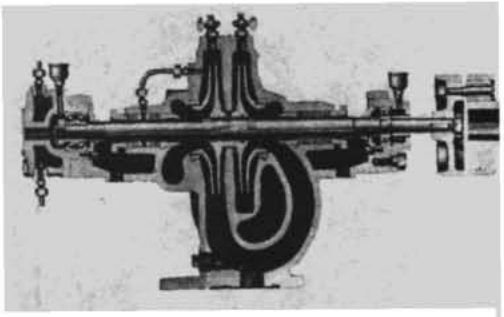
Some of the most interesting recent design developments are in pumps for process and nuclear-energy applications. To handle liquid metals, for example, we now have electromagnetic pumps, in which electrical energy is applied directly.

Electromagnetic pumps include the Faraday type for ac or dc power, the ac linear-induction design (a modification of this is called the Einstein-Szilard pump) and the electromagnetic centrifugal. These, and other similar designs, represent new approaches to the problem of moving a liquid from one point to another.

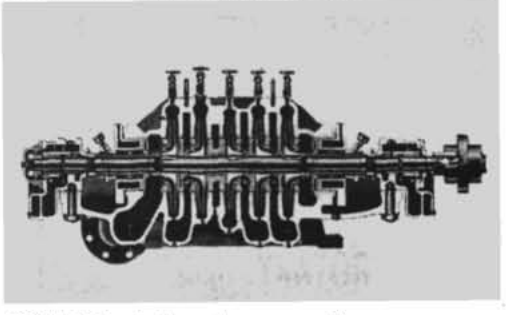
Among older ideas for moving liquids there are, of course, the familiar air lift, hydraulic rams, and the Humphrey pump. Here, however, we stick to common mechanical methods.



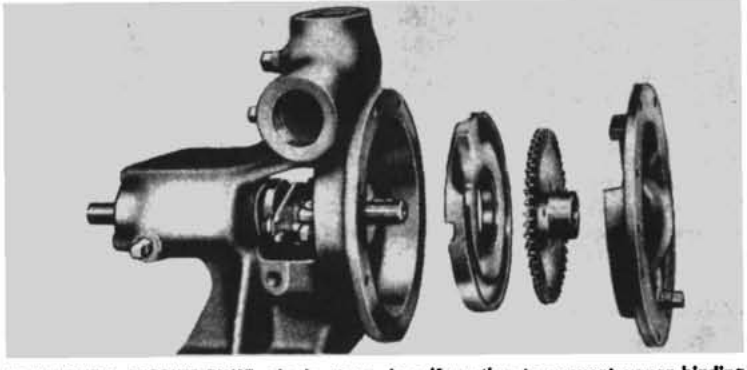
SINGLE-STAGE general-purpose pump has horizontally split casing, water-sealed stuffing boxes, cast-iron double-suction casing. The impeller is made of bronze



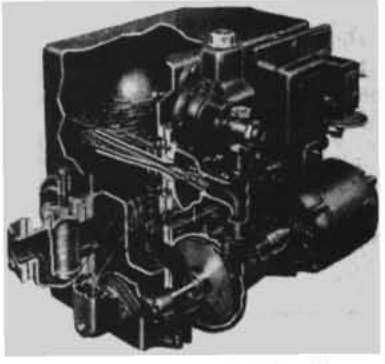
TWO-STAGE horizontally split pump has opposed impellers, ball-type bearings



MULTISTAGE single-suction opposed-impeller pump for continuous heavy duty



HORIZONTAL TURBINE PUMP, single stage, is self-venting to prevent vapor binding. Units like this are built with standard stuffing boxes, or with a mechanical seal



ENCLOSED-TYPE non-overload impeller on stainless-steel shaft for vacuum service

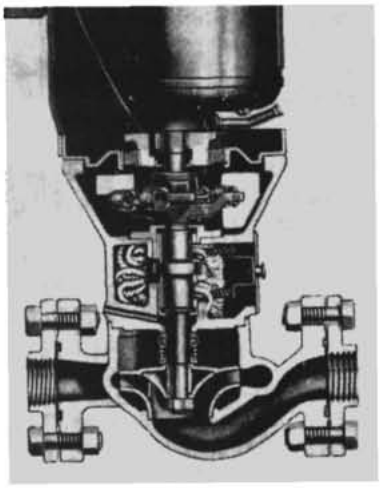
Centrifugal pumps

Earlier we saw how modern pumps are classified and typed. Now we're ready to take a closer look at centrifugal pumps – the most widely used units.

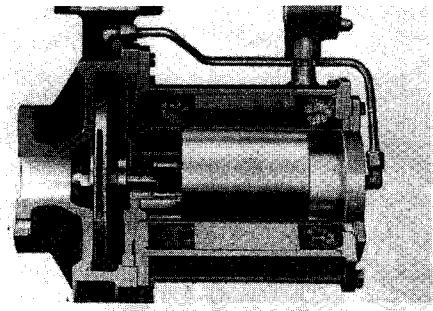
Illustrations on these two pages are a small sampling of today's designs. Study shows that though all come under one broad classification, intended application is a major factor in impeller and casing design, materials used, and other mechanical and hydraulic features. For these reasons we find pump builders stressing ultimate use somewhat more than classification and type.

Thus centrifugal pumps are termed boiler-feed, general-purpose, sump, deep-well, refinery (hot oil), condensate, vacuum (heating), process, sewage, trash, circulating, self-priming, sanitary, bait, booster, paper stock, chemical, fire, jet, sand, slurry, ash, glass, stoneware, submersible, tail-water, etc. In general, each has specific features of design and materials recommended by the builder for the particular service. This makes selection and application easier.

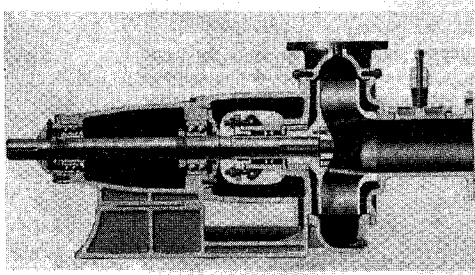
Another subdivision grows out of broad structural features. Thus we find horizontal and vertical units, close-coupled designs, single- and double-suction impellers, horizontally split casings and barrel casings, etc. Correct evaluation of all these variations is one of the big jobs in selecting a pump.



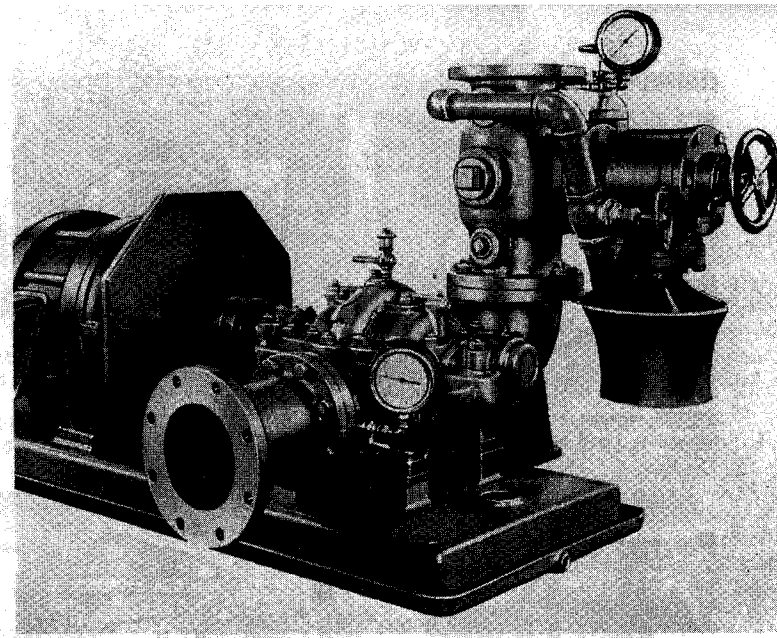
SINGLE-STAGE pump with sleeve bearings and mechanical seal for hot-water uses



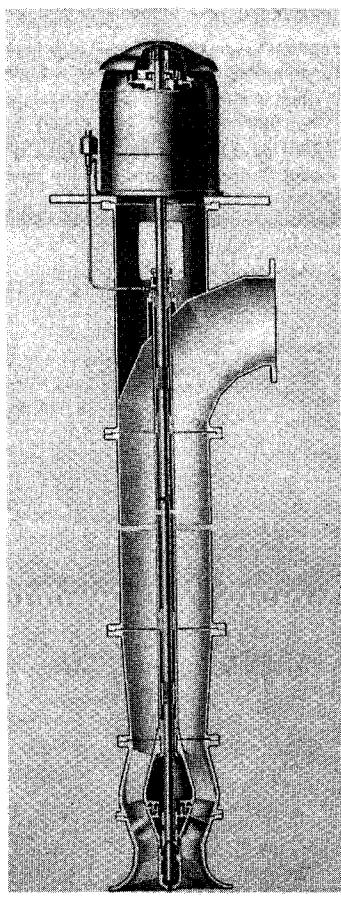
SEAL-LESS leakproof combined motor-pump has no stuffing boxes, uses no lubricant



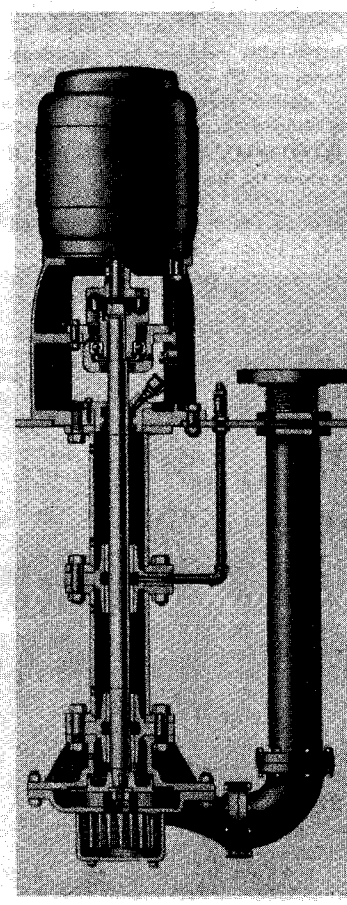
NON-CLOGGING PUMP: 2-bladed impeller, ball bearings, removable suction cover



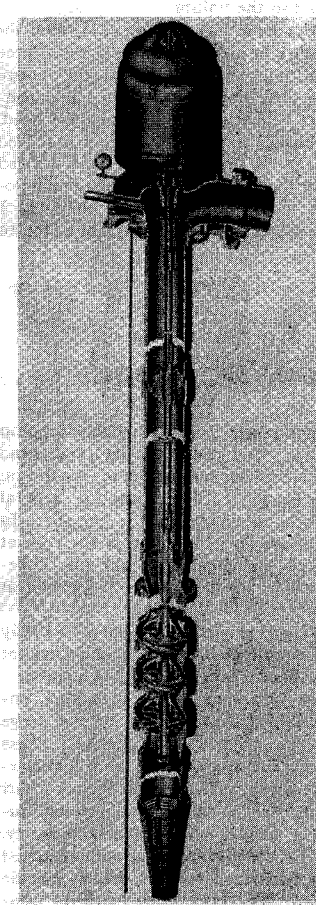
SUCTION SIDE of a single-stage fire pump, complete with motor and fittings. Pumps and fittings for this service are laboratory tested before underwriters' approval



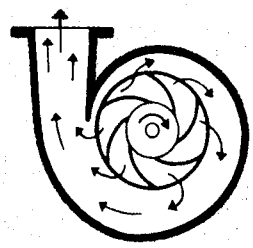
MIXED-FLOW vertical pump may be either water or oil lubricated, depending on job



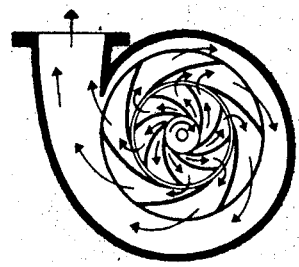
VERTICAL single-stage unit has semi-open impeller, ball and sleeve shaft bearings



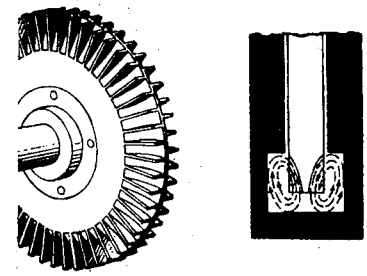
WATER-LUBRICATED vertical pump: semi-open impellers, open line-shaft bearings



VOLUTE converts velocity energy of the liquid into static pressure (read in psi)



DIFFUSER changes flow direction, aids in converting velocity energy to pressure



TURBINE pump adds energy to the liquid in a number of impulses during rotation

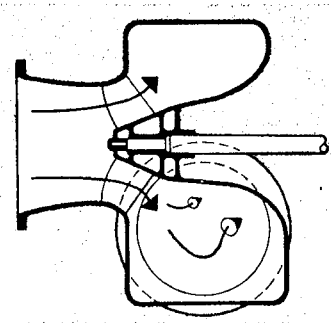
Pump action

In volute-type pumps the impeller discharges into a progressively expanding spiral casing, proportioned to gradually reduce liquid velocity. Thus velocity energy is changed to pressure head in the volute.

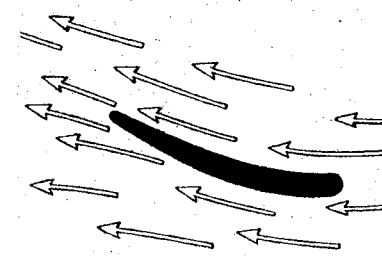
Stationary guide vanes surround the runner in a diffuser-type pump. These gradually expanding passages change the direction of liquid flow and convert velocity energy to pressure head.

Liquid in a turbine pump is picked up by the impeller's vanes and whirled at a high velocity for nearly one revolution in an annular channel in which the impeller turns. Energy is added to the liquid in a number of impulses, so it enters the discharge at high velocity.

Mixed-flow pumps develop their head partly by centrifugal force and partly by the lift of the vanes on the liquid. Propeller pumps develop most of their head by the propelling or lifting action of the vanes on the liquid.



MIXED-FLOW units use both centrifugal force and lift of vanes on the liquid



PROPELLER pump develops most of its head by propelling action of vanes on liquid

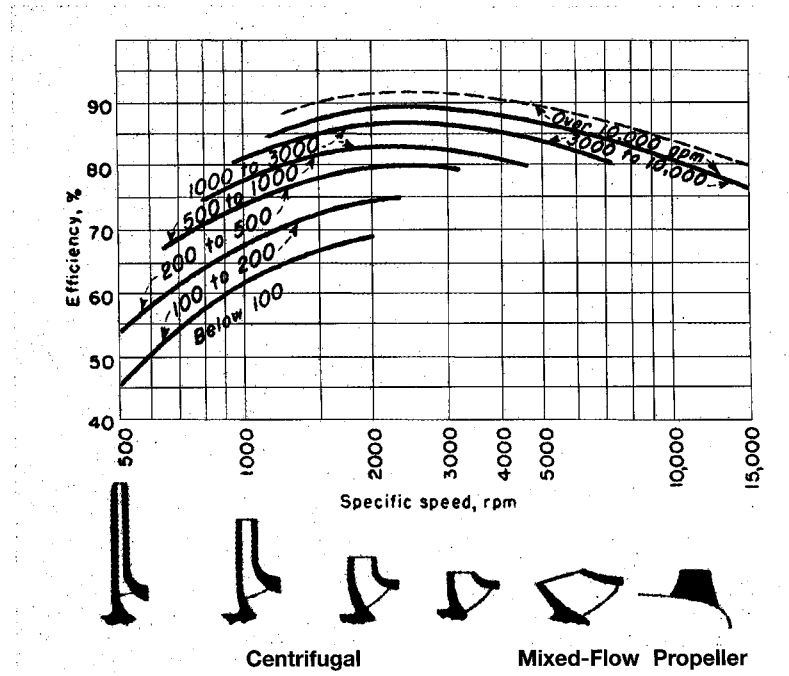
Specific speed

Specific speed is an index of pump type, using the capacity and head obtained at the point of maximum efficiency. It determines the general profile or shape of the impeller. In numbers, specific speed is the rpm at which an impeller would run if reduced in size to deliver 1 gpm against a total head of 1 ft.

Impellers for high heads usually have low specific speed; impellers for low heads have high specific speed.

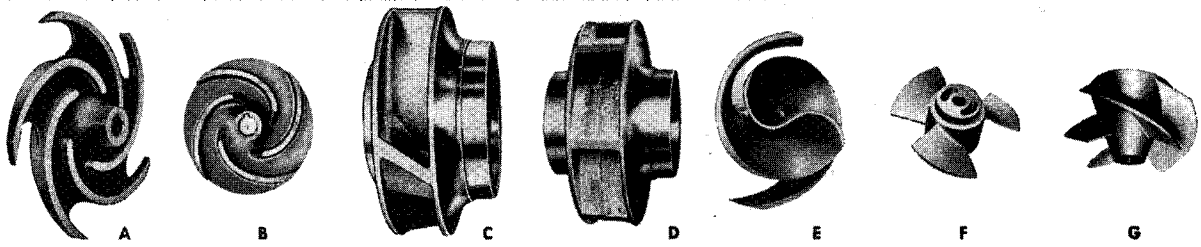
As diagram, *right,* shows, each impeller design has a specific-speed range for which it is best adapted. These ranges are approximate, without clear-cut divisions between them. Chart gives general relations between impeller shape, efficiency and capacity.

Suction limitations of different pumps bear a relation to the specific speed. The Hydraulic Institute publishes charts giving recommended specific speed limits for various conditions.



SPECIFIC SPEED is approximately related to impeller shape and efficiency, as shown by these curves. There is no sharp dividing line between various impeller designs

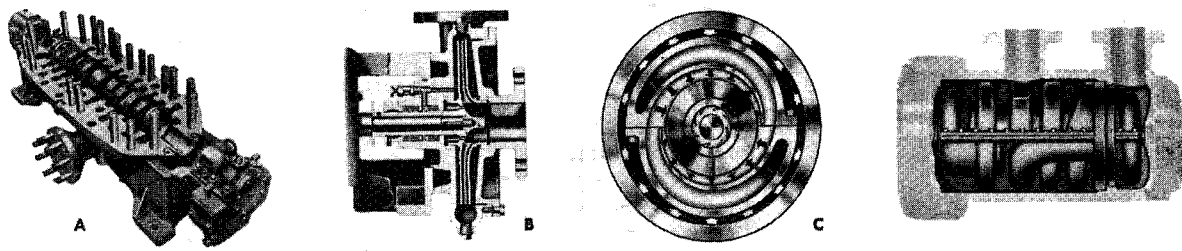
Impellers



Besides being classified according to specific speed, an impeller is also typed as to how the liquid enters, its vane details, and use for which it is intended.

Open impellers, *A*, have vanes attached to a central hub with relatively small shrouds. *Semi-open, B,* have a shroud, or wall, on only one side. *Closed* impellers, *C* and *D*, have shrouds on both sides to enclose liquid passages. *Single* or *end-suction* units, *C*, have liquid inlet on one side; in *double-suction* type, *D*, liquid enters both sides. *E, F* and *G are paper-stock, propeller and mixed-flow* designs.

Casings

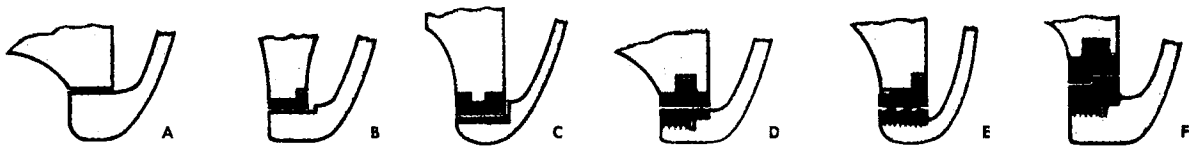


Centrifugal-pump casings may be split *horizontally, A, vertically, B,* or *diagonally* (at an angle other than 90 deg).

Horizontally split casings are also termed *axially* split. Both suction and discharge nozzles are normally in lower half of casing; upper half lifts for easy inspection. Vertically split casings are also called *radially* split. They're used in close-coupled or frame-mounted end-suction designs.

Barrel casings, C and *D*, are used on high-pressure diffuser and volute pumps. Inner casing fits in outer barrel. Discharge pressure acting on inner case provides seal.

Wearing rings

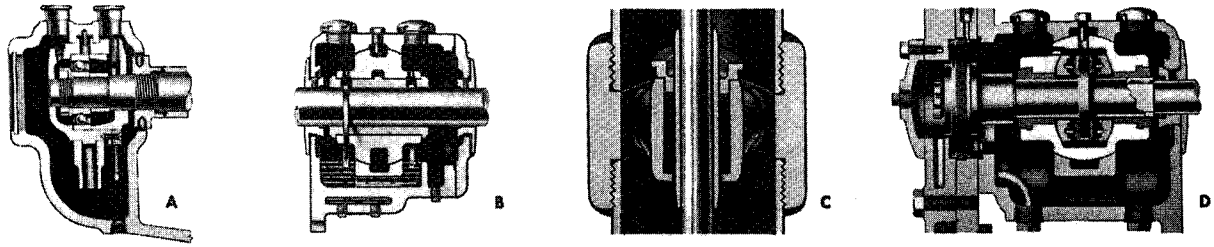


To prevent costly wear of casing and impeller at the running joint, wearing rings, also called casing rings, are installed. Where these rings are removable, as they usually are, they can be replaced at a fraction of the cost of a new impeller or pump casing that might otherwise be needed.

Seal *A* is a plain flat joint. Similar joint, *B*, has a flat ring mounted on the pump casing. At *C* the ring fits into a casing groove; impeller has a similar ring.

In designs *D, E,* and *F*, rings are fitted to both casing and impeller. Form varies with pressure, service, etc.

Bearings



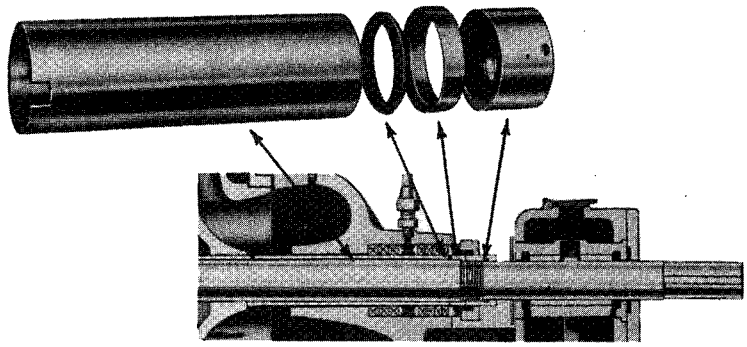
Practically every type of bearing has been used in centrifugal pumps. Today, *ball, sleeve* and *Kingsbury* bearings find most common use. Many pumps are available with more than one type of bearing to meet different needs.

Ball bearings, *A*, may be of single- or double-row type. Spherical roller bearings are widely used for large shafts.

Sleeve bearings, *B* and *C*, may be either horizontal or vertical. In the latter, water is often the lubricant.

Kingsbury thrust bearings, *D*, find use in larger pumps. Design resembles that used in other rotating machinery.

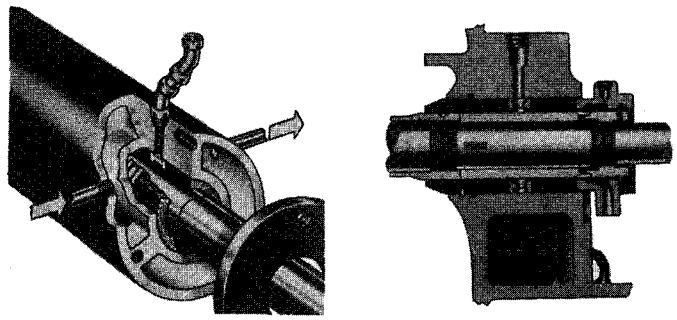
Shaft and interstage sleeves



Sleeves protect shaft against corrosion, erosion and wear affecting its strength. Many forms are used on large pumps but on small ones sleeve is often left off to cut hydraulic and stuffingbox losses. Shaft is then made of a metal that is sufficiently corrosion- and wear-resistant for satisfactory life.

Interstage sleeves guard multistage pump shafts. In some, long hub on impeller replaces interstage sleeve.

Lantern rings

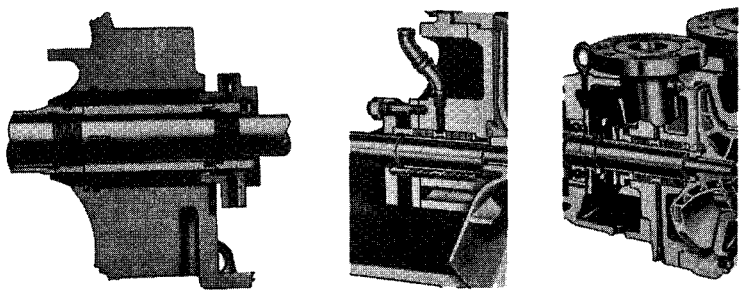


These are used to prevent air leakage into pump when running with a suction lift and to distribute sealing liquid uniformly around annular space between box core, shaft-sleeve surface.

Also called seal cages and waterseal rings, they receive liquid under pressure from pump or independent source.

Grease sometimes serves as sealing medium when clear liquid isn't available or can't be used (sewage pumps).

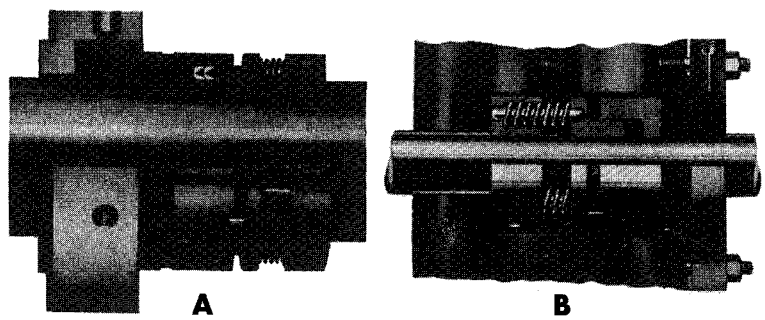
Stuffing boxes



Stuffing box stops air leaking into casing when pressure is below atmospheric; holds leakage out of casing to a minimum when pressure is above.

Sketches show solid-packed box, which has no lantern rings; two injection designs, which do. On pumps handling hot liquids, or having high stuffing-box pressures, box is often water-jacket cooled. In some, coolant and pumped liquid mix.

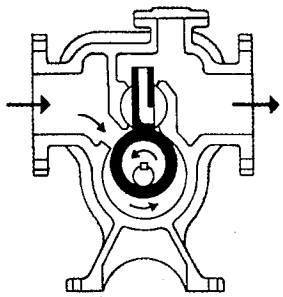
Mechanical seals



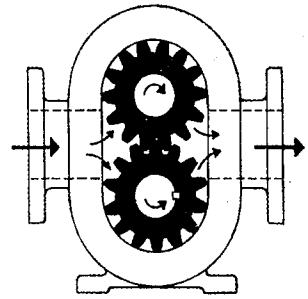
Mechanical seals in wide variety serve where leakage is objectionable. They also find use where stuffing-boxes can't give adequate leak protection.

Sealing surfaces are perpendicular to pump shaft and usually comprise two polished lubricated parts running on each other. Though not guaranteed leakproof, leakage is usually nil.

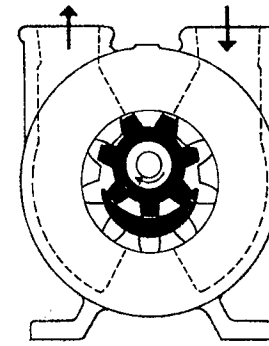
Outside type, *A*, is used where gritty liquids or leakage retained in stuffing box would be undesirable. *Inside*, *B*, finds much use for volatile liquids.



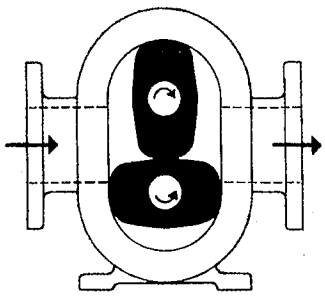
CAM-AND-PISTON



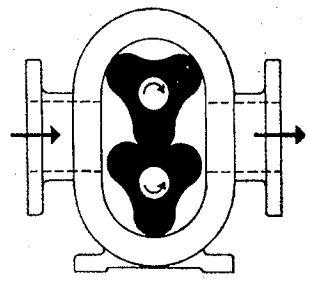
EXTERNAL-GEAR



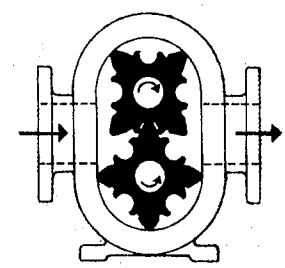
INTERNAL-GEAR



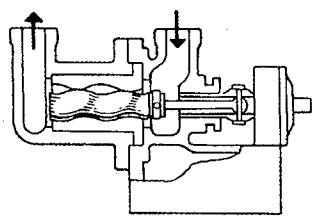
TWO-LOBE



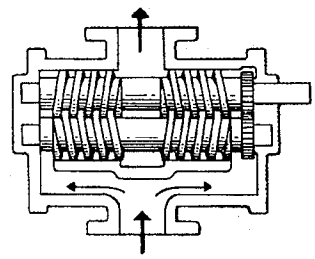
THREE-LOBE



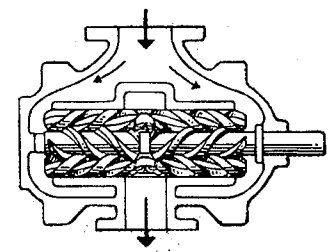
FOUR-LOBE



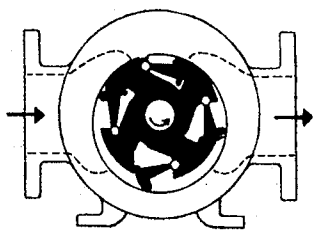
SINGLE-SCREW



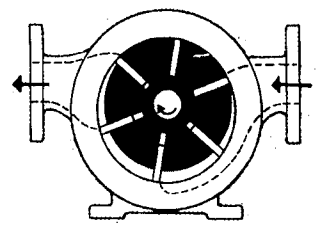
TWO-SCREW



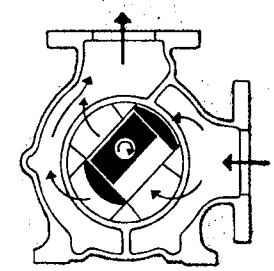
THREE-SCREW



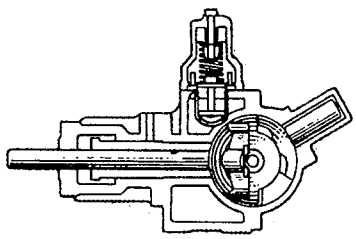
SWINGING-VANE



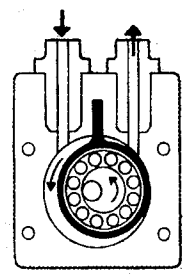
SLIDING-VANE



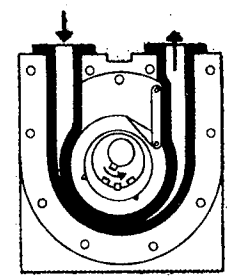
SHUTTLE-BLOCK



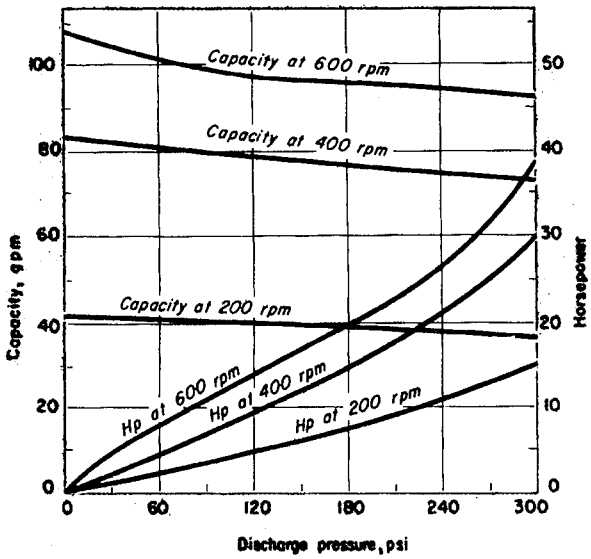
UNIVERSAL-JOINT



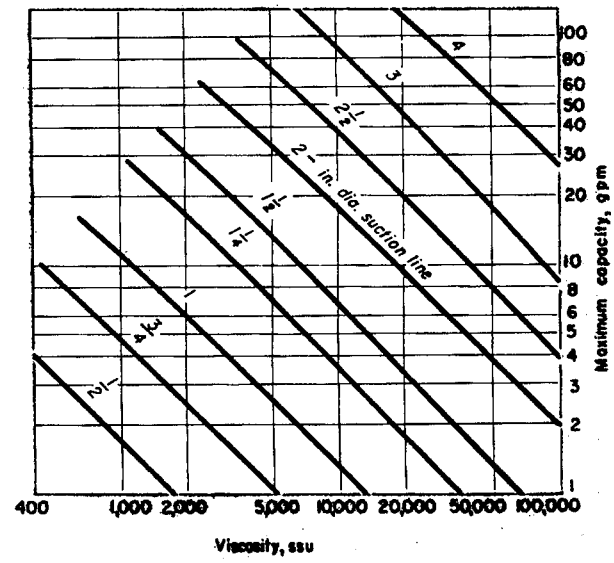
ECCENTRIC IN FLEXIBLE CHAMBER



FLEXIBLE-TUBE



CAPACITY and horsepower performance curves of a gear-type rotary pump handling heavy fuel oil. Note the flat *H-Q* curves



RECOMMENDED SIZE of suction piping for viscous liquids in 10 ft of straight pipe with two elbows and one gate valve

Rotary pumps

Rotary pumps, usually positive-displacement units, consist of a fixed casing containing gears, vanes, pistons, cams, segments, screws, etc, operating with minimum clearance. Instead of "throwing" liquid as in a centrifugal, rotaries trap it, pushing it around the closed casing, much like reciprocating pumps. But unlike a piston pump, a rotary discharges a smooth flow.

Fifteen designs, *left*, illustrate a few of the devices chosen to move fluids from one point to another. Often thought of as viscous-liquid pumps, rotaries are by no means confined to this service alone. They'll handle any liquids from A to Z, if free of hard solids. And hard solids can be handled if steam jacketing will melt them. As with centrifugals, materials and drives vary with job, liquid, etc.

Cam-and-piston pumps, also called rotary-plunger type, consist of an eccentric with a slotted arm at its top. Shaft rotation causes eccentric to trap liquid in casing, discharges it through slot to outlet.

External-gear pumps are the simplest rotary type. Liquid first fills the spaces between gear teeth as they separate on suction side, is then carried around and squeezed out as the teeth mesh. Gears may have spur, single- or double-helical teeth. Some designs have drilled idler to cut internal thrust.

Internal-gear pumps have one rotor with internally cut teeth meshing with an externally cut gear idler. Crescent-shaped partition, to prevent liquid from passing back to suction side, may or may not be used.

Lobular pumps resemble the gear-type in action, have two or more rotors cut with two, three, four or more lobes on each rotor, synchronized for positive rotation by external gears.

Single-screw pumps have a spiraled rotor turning eccentrically in an internal-helix stator or liner. Rotor is metal while helix is hard or soft rubber.

Two- and three-screw pumps have one or two idlers, respectively. Flow is between the screw threads along the axis of the screws. Opposed screws may be used to eliminate end thrust.

Swinging-vane pumps have a series of hinged vanes which swing out as the rotor turns, trapping liquid and forcing it out the discharge pipe.

Sliding-vane pumps use vanes that are thrown against casing bore when rotor turns. Liquid trapped between two vanes is carried around and forced out the discharge.

Shuttle-block pump has a cylindrical rotor turning in a concentric casing. In the rotor is a shuttle block and piston reciprocated by an eccentrically located idler pin, producing suction and discharge.

Universal-joint pump has a stub shaft in free end of rotor supported in a bearing at about 30 deg with the horizontal. Opposite end of rotor is fixed to drive shaft. When rotor revolves, four sets of flat surfaces open and close for a pumping action of four discharges per revolution.

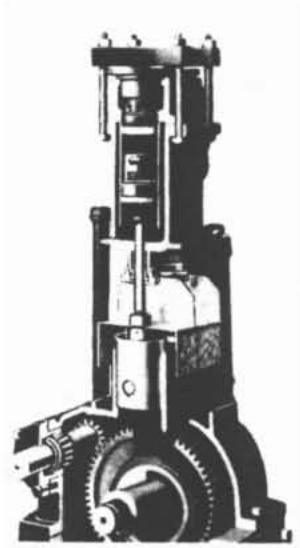
Eccentric in flexible chamber produces pumping action by squeezing the flexible member against pump housing to force liquid out discharge.

Flexible-tube pump has a rubber tube squeezed by a compression ring on an adjustable eccentric. Pumps of this design are built single- and 2-stage.

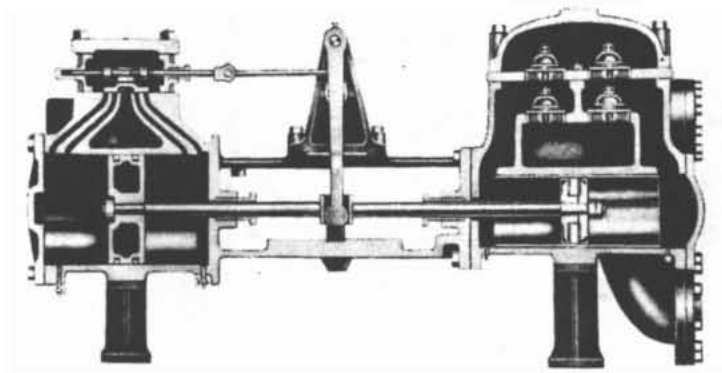
Characteristic curves, *above left*, for a typical rotary gear pump show the flat *H-Q* relation obtainable. Displacement of a rotary varies directly as speed, except as capacity may be affected by viscosity and other factors. Thick liquids may limit pump capacity at higher speeds because they can't flow into casing fast enough.

Slip or loss in capacity through clearances between the casing and rotating element, assuming a constant viscosity, varies as pressure increases. For example, in above curves, capacity at 0 discharge pressure is 108 gpm. But at 300 psi and same speed, capacity is 92 gpm. Difference is slip.

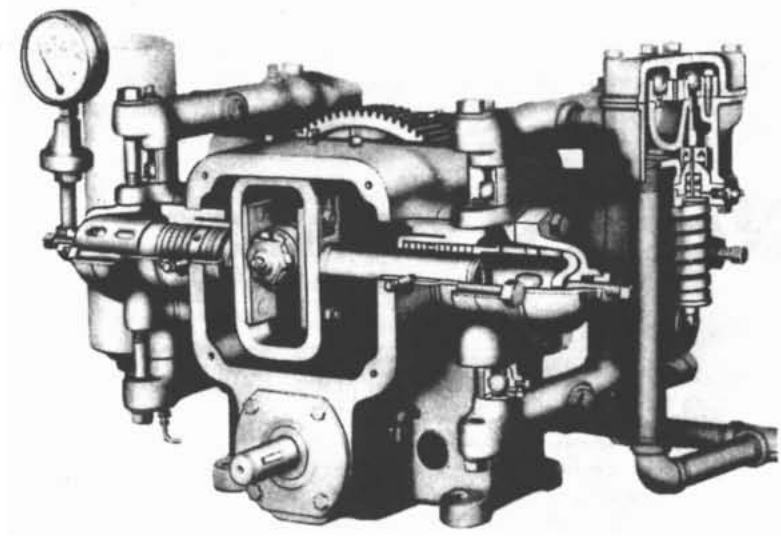
Power input to a rotary increases with liquid viscosity; efficiency decreases. This is true, of course, with other classes of pumps. But since rotaries find wide use for viscous liquids, it is wise to use the chart, *above right*, for sizing suction lines to prevent excessive friction loss.



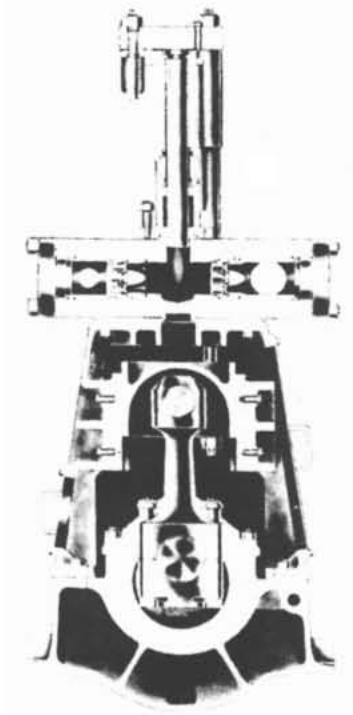
SINGLE-ACTING vertical-type power pump has pinion shaft for driving crankshaft



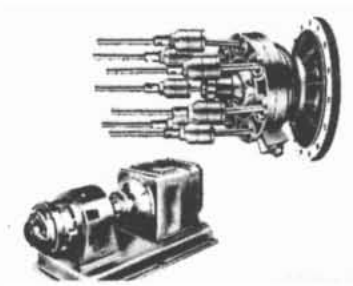
DIRECT-ACTING horizontal duplex piston pump. Steam end is at left, liquid end is at right. Piston-rod motion shifts steam valve for admission and exhaust of the steam



QUADRUPLEX horizontal-plunger power pump for high pressures is motor driven through pinion and gear. Each Scotch yoke drives two plungers. Pump valves are the ball type



INVERTED triplex vertical-plunger power pump for high-pressure job applications



ROTARY-PLUNGER single-acting pump unit has five or seven plungers in a circle

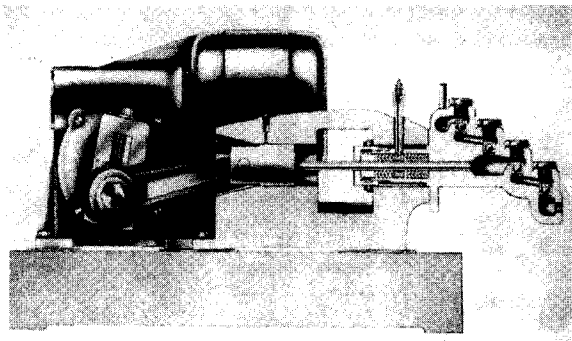
Reciprocating pumps

The 13 pumps on these two pages are but a few of the many reciprocating types in regular use today. But you will find shown here most of the major designs.

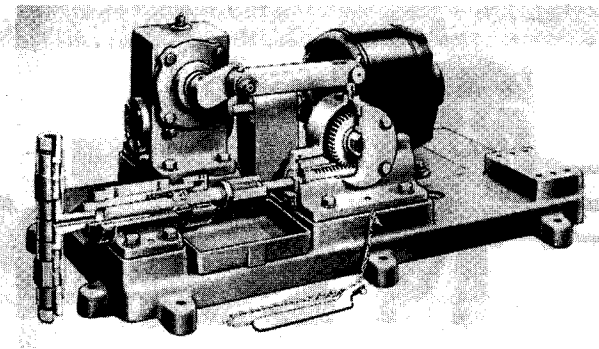
Reciprocating pumps, unlike centrifugals, p 80, are more often classed according to type, rather than use. Perhaps this is because their ultimate use is less clearly defined than for centrifugal pumps. While certain applications for this type, like fuel-oil pumping, are declining, others, like boiler and chemical feeding, are rising.

Biggest recent developments are in non-geared higher speed power pumps – both large and small units. Adjustable displacement pumps, also called metering and proportioning or controlled-volume, are being improved every year to give wider capacity ranges, greater accuracy, easier control.

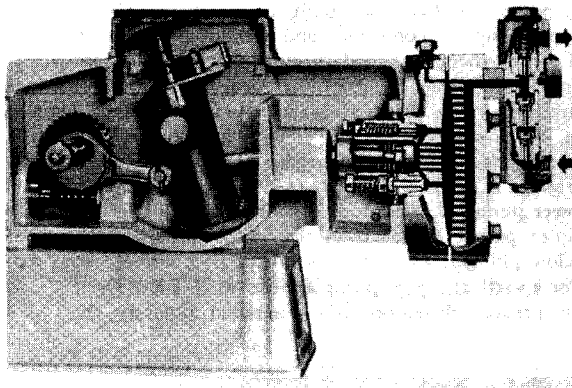
Power pumps, always of importance in the marine field for boiler feed are finding some new berths in stationary plants for the same service where loads justify them. And if pressures in superpressure plants rise, it is likely that power-type reciprocating pumps will be used for boiler feed. Of course, much depends on new developments in the design of centrifugal pumps.



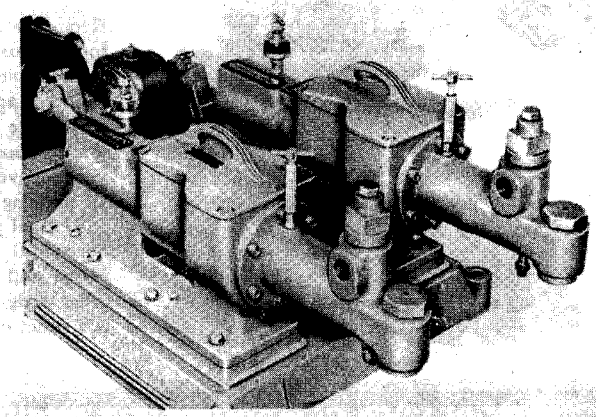
CONTROLLED-VOLUME plunger pump has screw adjustment of stroke length. Change of crankpin position alters capacity of pump



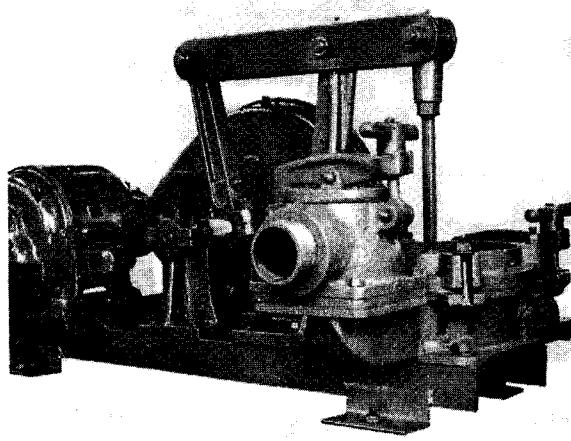
METERING and proportioning plunger pump has lost-motion type of coupling for adjusting stroke length and capacity of pump



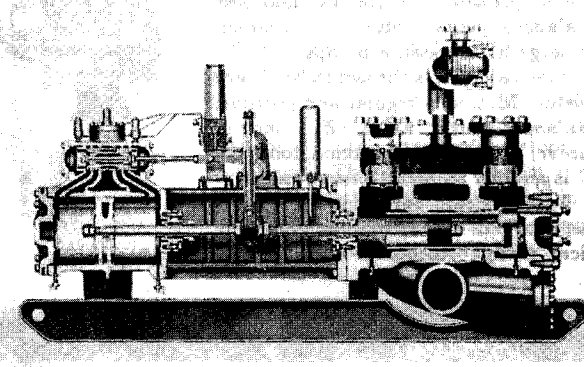
PISTON-DIAPHRAGM unit for controlled-volume pumping has oil for actuation of diaphragm which pumps the liquid handled



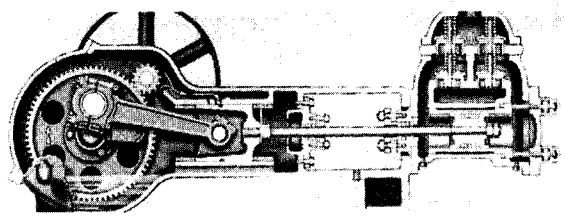
DUPLEX plunger-type feeder pump has micrometer adjustment of stroke length by means of variation of the crankpin position



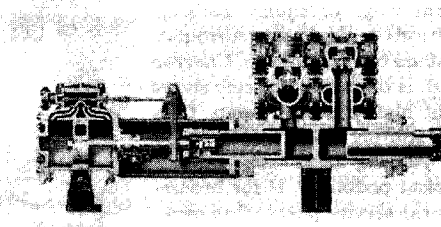
DIAPHRAGM pump with ball suction and discharge valves is built with stationary or movable base, is motor driven through beam



DUPLEX STEAM slush pump has divided-cylinder pot-type liquid end with suction manifold at the bottom of the liquid cylinder

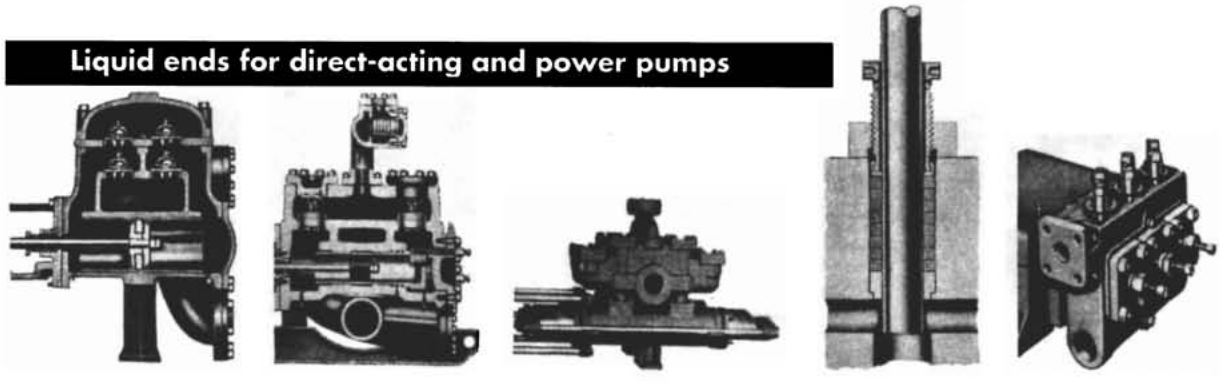


HORIZONTAL SIMPLEX power pump is driven by pinion geared to crankshaft, has disk-type suction, discharge valves, air dome



HORIZONTAL DUPLEX outside-end-packed pot-valve-type plunger pump: the plungers shown are attached together by the tie rods

Liquid ends for direct-acting and power pumps



Reciprocating-pump liquid ends are built in a large number of designs for various liquids, service conditions and pressures. Shown above are a few typical arrangements for modern pumps.

Direct-acting steam pump, *A*, often has *valve-plate* liquid end with removable discharge-valve decks. Cup-type packing for liquid piston is also shown. *Valve-pot* type, *B*, has valve chambers closed by individual covers. *Outside-packed* plunger pump, *C*, has its valves in pots—all packing leakage is external where it can be seen.

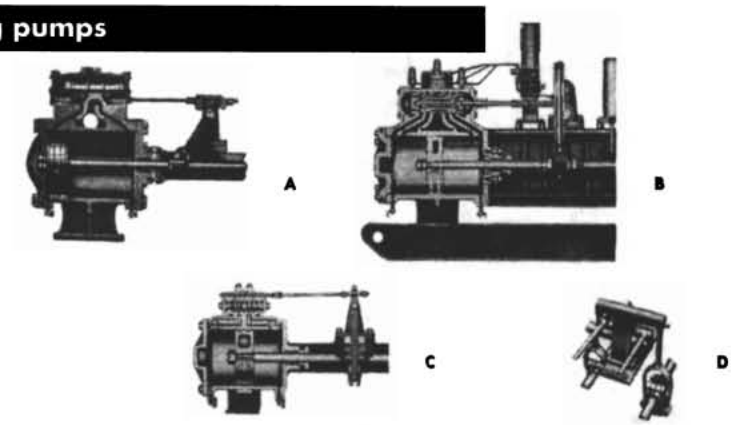
Vertical power pump, *D*, has plunger packing at cylinder top, while horizontal triplex pump, *E*, has it in the usual location with valves above and below plunger. At *F*, valves are in step arrangement. Another design for a vertical triplex pump appears at *G*. Liquid-end design is a function of pressure developed, liquid handled, capacity, etc.

Steam ends direct-acting pumps

Flat or 'D' slide valves find use for steam pressures of 200 psi and less Balanced piston valves are common in large high-pressure pumps.

Flat valve, A, is thrown by auxiliary piston. Motion is regular and positive. *Balanced-piston valve, B,* runs in sleeve, has minimum friction, long life. *C* is another *balanced-piston* valve.

Typical steam-valve linkage, *D,* connects to rod. Steam-end design of vertical pumps resembles those shown.

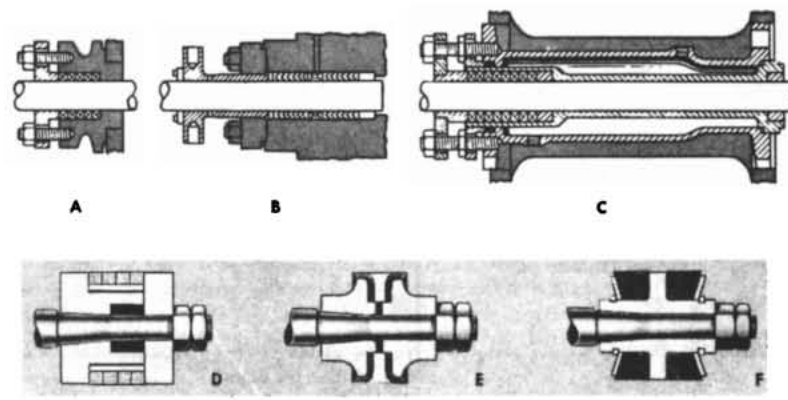


Packing

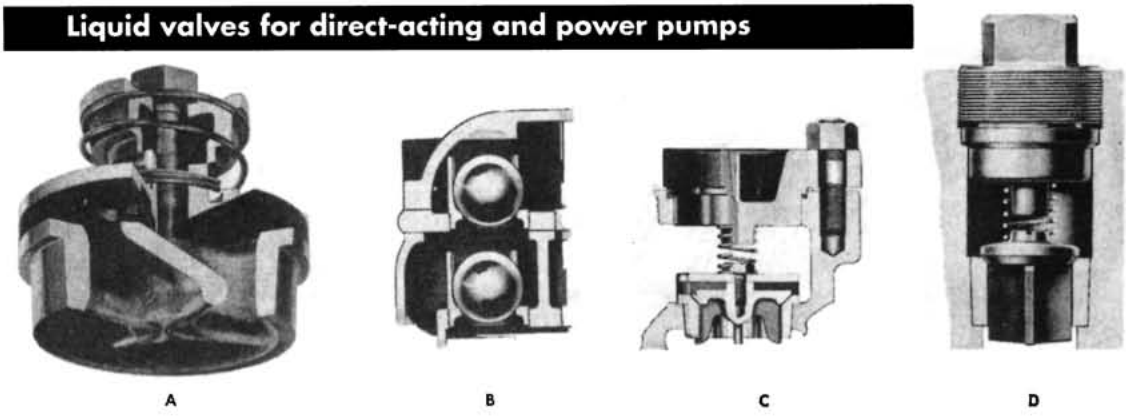
Packing is any material used to control leakage between a moving and stationary part in a pump. Flexible, and usually soft, it is expendable.

Simple piston-rod stuffing box, *A,* has several rings of square packing. On small rods a single nut surrounds gland, instead of studs shown. *Chevron* packing, *B,* is often used. Sketch shows plunger of high-pressure pump. *C* is a jacketed stuffing box.

Piston packing takes many forms. *Duck-packed* piston, *D,* is for bronze-fitted general-service pump. *Cup* packing, *E,* is standard for oil pumps. *Solid rubber rings, F,* are also popular.



Liquid valves for direct-acting and power pumps

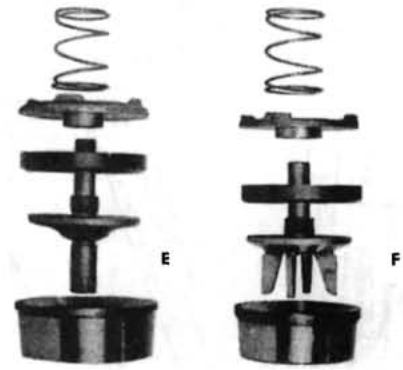


A B C D

As a general rule, stem-guided disk valves are used for low-pressure jobs, wing-guided (flat- or bevel-faced) for moderate pressures, and bevel-faced wing for high pressures. But much depends on liquid, etc.

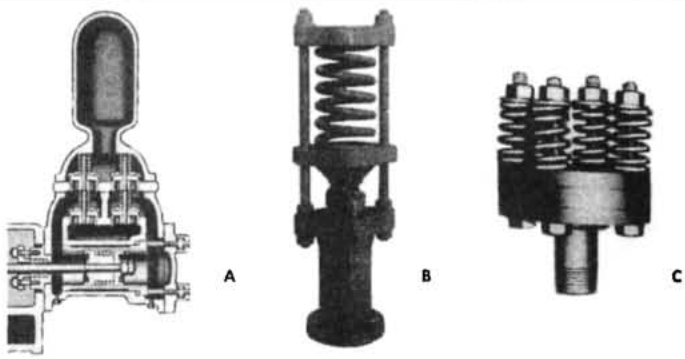
Flat disk, A, has inclined ribs in seat to direct liquid so it rotates disk slightly at each stroke. *Ball valve, B,* often finds use where free opening for thick liquid is desired. Cage guides ball during its rise and fall. Seat is circular and completely open. *Wing-guided* valve, *C,* for thick gritty liquids, can be fitted with renewable rubber inserts for wings. Another design, *D,* for high-pressure clear liquids, has renewable seats.

Low-pressure valve, *E,* and *high-pressure* valve, *F,* for thick liquids are alloy-steel with synthetic inserts for all ordinary services. Special materials are used where corrosive liquids are to be handled. Double-ported ring-type valves, *G,* p 92, are popular in large power pumps.



E F

Cushion chambers and pressure alleviators

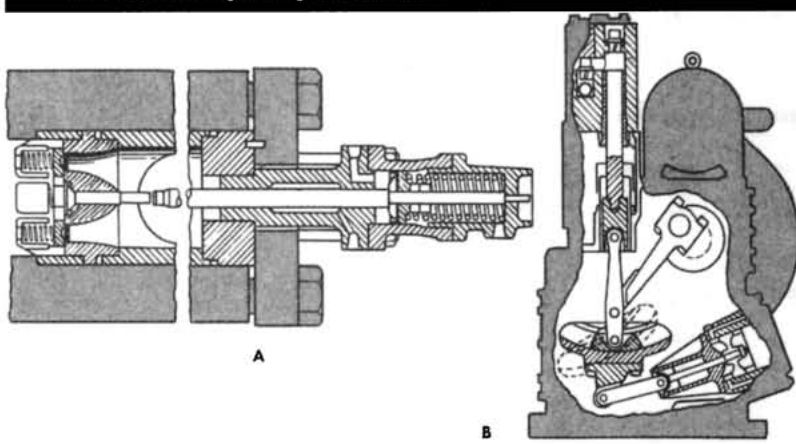


A B C

Suction and *discharge cushion chambers* smooth liquid flow. Discharge chamber, *A,* is often built as part of pump while suction chamber may be part of pump or in adjacent piping.

Pressure alleviators, *B* and *C,* find use with high-pressure power pumps to absorb shock from sudden stopping of liquid. They usually consist of a spring-loaded plunger operating in a stuffingbox. Liquid does not escape from piping system during surges.

Variable-capacity devices

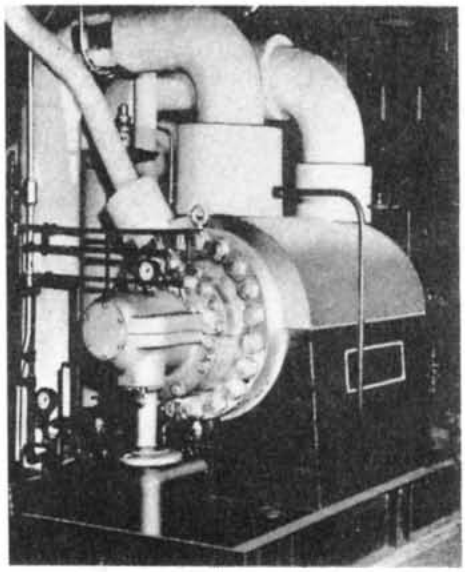


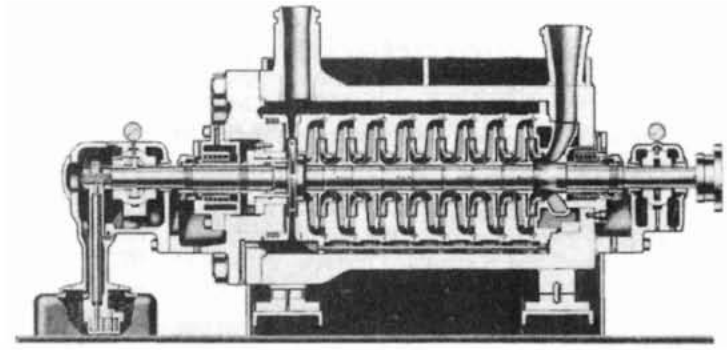
A B

There seems no end to devices for varying capacity of small reciprocating pumps. A few appear on pp 90-91. For large power pumps, however, not so many variations exist perhaps because of the lesser number of designs.

Suction-valve unloader, A, gives a quick but gradual reduction in liquid delivery from full to zero flow in not more than one-half revolution of pump. It increases liquid delivery in same way, is pneumatically actuated.

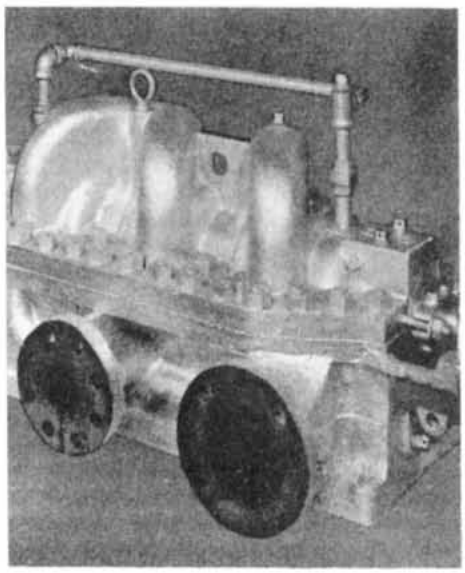
Stroke-transformer, B, can automatically or manually vary plunger motion from zero to maximum stroke. Output is infinitely controllable.

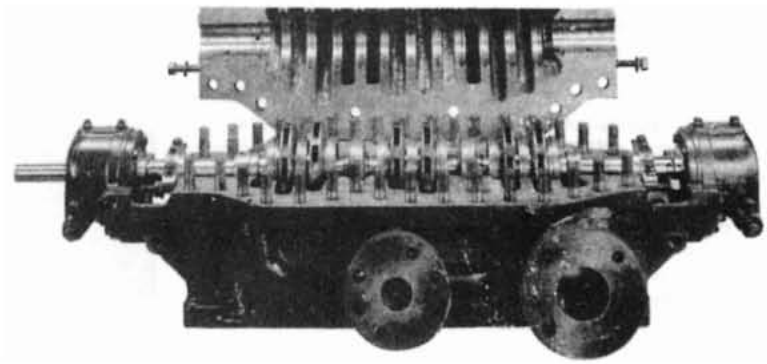




High-pressure boiler feed

The modern double-case barrel-type centrifugal pump is today's answer for pressures approaching 6000 psi and temperatures to 1000 F. In the common 2600-psi range, units of this type run at about 3600 rpm, have up to 12 stages. The first superpressure plant uses two pumps of this type in series, with heaters between. Note how vertically split inner assemblv is housed in casing.





Medium- and high-pressure boiler feed

Horizontal split-case diffuser-type pumps with about six stages are common for 3600-rpm duty at pressures to 1600 psi. Some thinking today sees these units applied up to 2500 psi, but that is in the future. Design shown is 6-stage with back-to-back impellers in groups of two for better hydraulic balance. A big advantage of this type of pump is easy removal of top for maintenance.

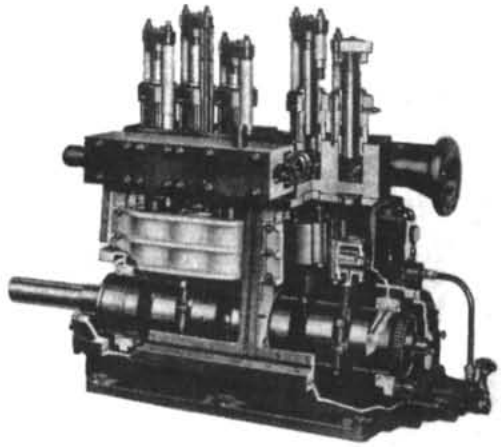
Pump applications

Any attempt to list every possible application of pumps is almost certain to run aground because editors, being human, might overlook important jobs like pumping goldfish, apples, oranges, eggs and beer.

So these two pages, and the following four, give a necessarily selective cross section of pump classes and types *on the job*. There lies the ultimate goal of pump designers and builders—a product that performs a given service at the best over-all cost with minimum operating and maintenance needs. To secure these results the pump must be suited to the job, installed correctly, operated and maintained as the builder recommends. For now, let's take a quick look at application.

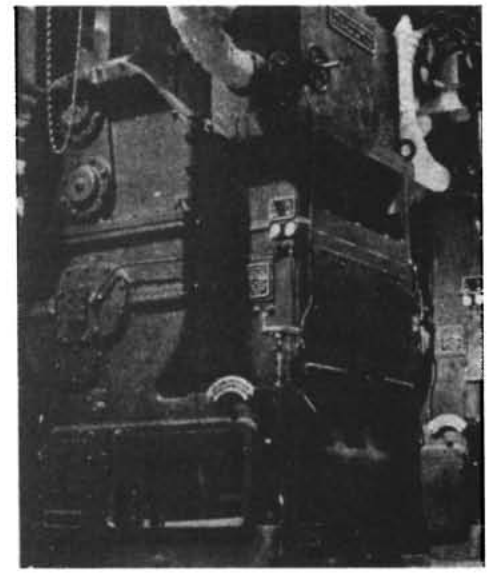
Pump class, type, drive and materials are among the major factors in unit selection. While generalizations are often dangerous, studies of a large number of modern installations show that industrial and service establishments throughout the U. S. use centrifugals for about 60% of their jobs, reciprocating for about 22%, rotary for about 12% and deepwell for about 6%. About 86% of the centrifugals have motor-drive, 44% of reciprocating, 96% of rotary and 95% of deepwell. Steam engines, turbines and internal-combustion engines drive about 13% of the centrifugals. Steam is outstanding for reciprocating units, driving almost half of those in use.

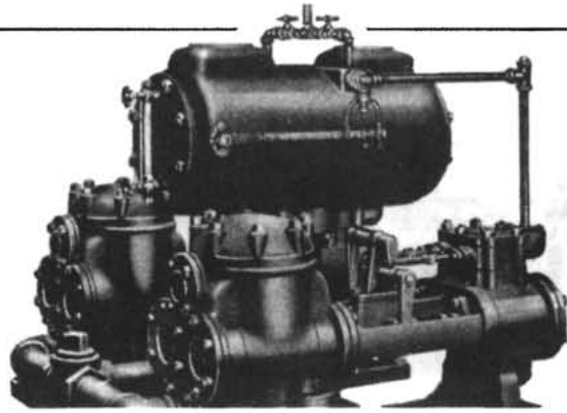
While these statistics are helpful from an over-all viewpoint, they serve merely as a guide to what industry is doing today. For help with a specific installation, the text and illustrations on these six pages will lead you through the maze of classes and types toward a sound answer.



Power reciprocating for boiler feed

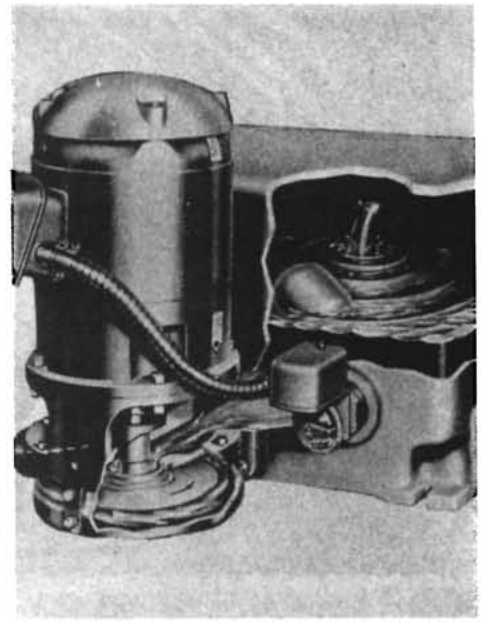
At pressures over about 250 psi where load is variable, power reciprocating pumps find application. They are also used for desuperheater feed in this pressure range. Vertical quintuplex units like that above are popular in feed service because they are easy to control automatically in stepless straight-line fashion from 0 to 100% of rated capacity. Use is now on the upswing.

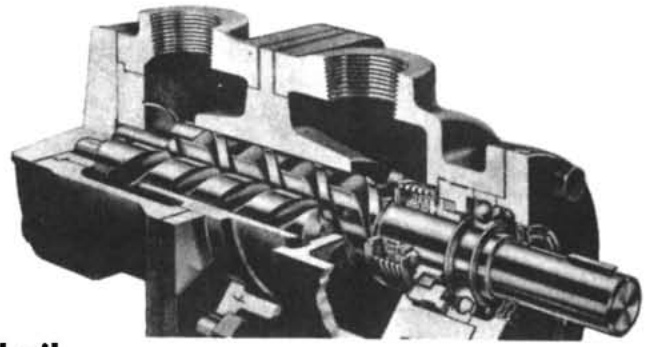




Low-pressure boiler feed

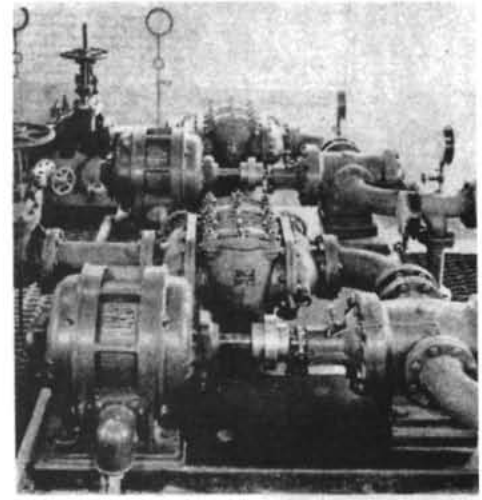
Direct-acting pumps, with or without receiver, find use in smaller low-pressure boiler installations. Simple, rugged and economical, they give outstanding service. Though not always classed as feed pumps, centrifugal condensation sets, *right*, are extremely popular in heating and similar installations. Compact and efficient, they handle wide temperature, pressure, capacity ranges.

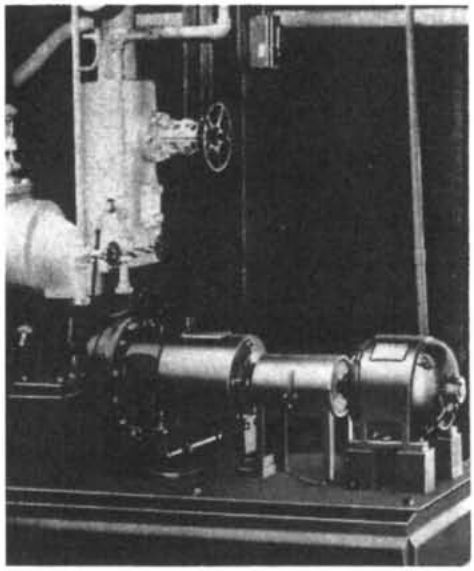


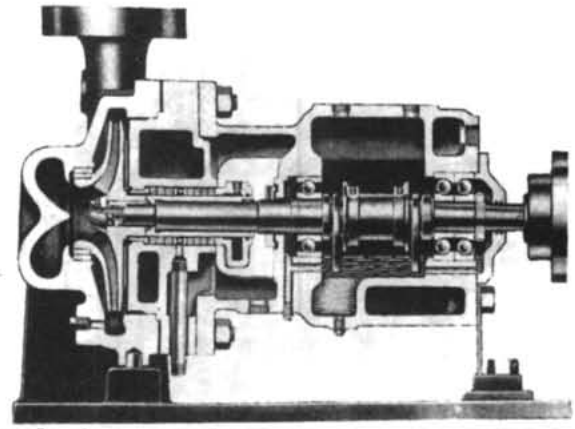


Fuel oil

Screw and gear pumps are the modern units for fuel-oil pumping but direct-acting steam pumps still do the job in some plants. Screw pump shown handles up to 80 gpm at continuous pressures of 275 psig, intermittent to 325 psig. Pumps of this type find many other uses besides fuel-oil pumping, including lubrication, booster, circulating, governing and elevator jobs.

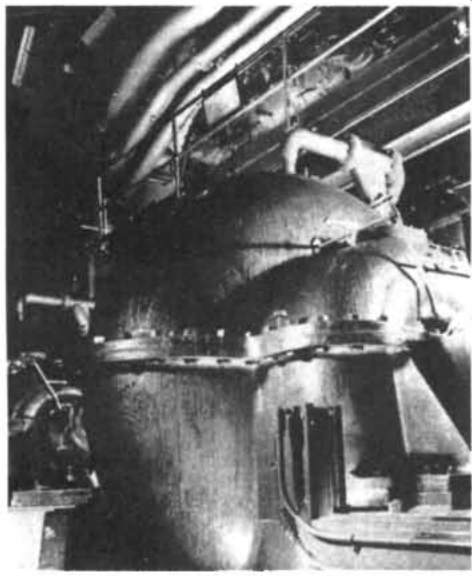


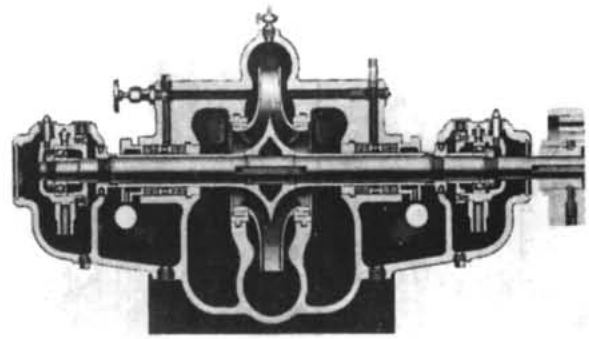




Heater drains, condensate

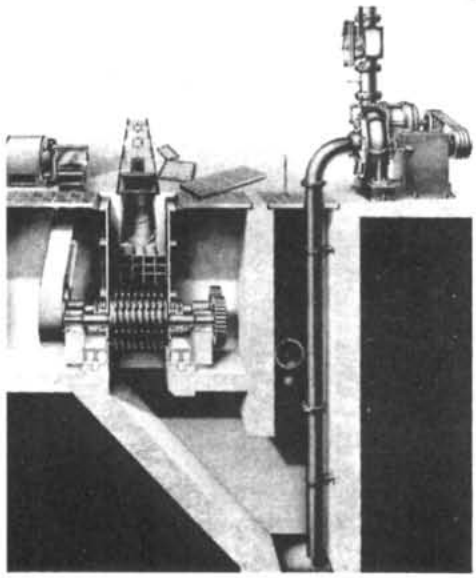
Handling condensate from hotwells, heater drains and other sources may impose severe operating conditions on a pump. In condenser service, suction head is low, liquid is near the boiling point, suction seal is a minimum and load changes wide. Usual centrifugal condensate pumps have one to four stages, special sealing and balancing features. Unit shown is single-stage.

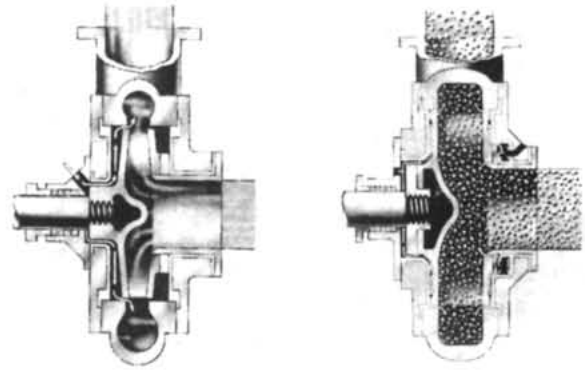




Cooling water

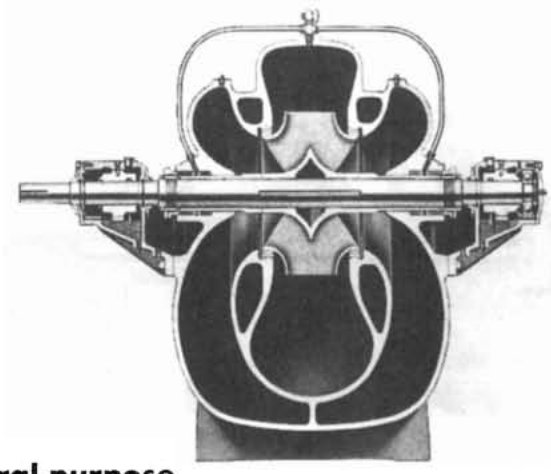
Whether tremendous, like the 55,000-gpm unit at left, or tiny as those on a small air conditioner, cooling-water pumps have some common traits. They are usually single-stage, standard-fitted, split-case. In the larger capacities they are often horizontal units, though many vertical designs are also used, both large and small. Their duty is seldom severe; operation is trouble-free.

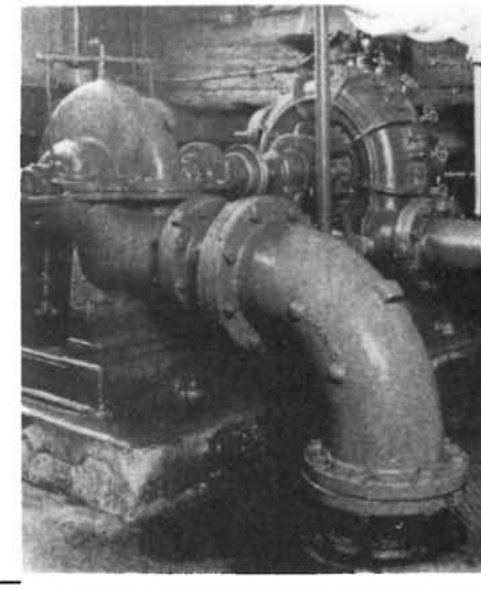




Handling ash, abrasive solids

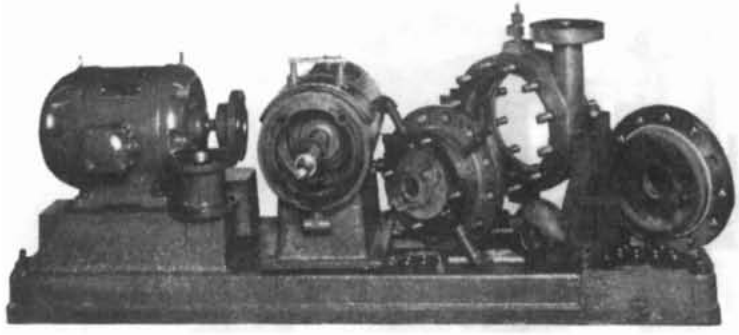
In contrast to cooling-water service, handling abrasive solids of any kind imposes many special problems on a pump. Rubber-lined units with special seals, as shown, are one good answer for ashes, sand, etc. Other designs include packingless types, flat-blade impellers and special arrangements for suction inlet. While the pump is important, so are other system details.

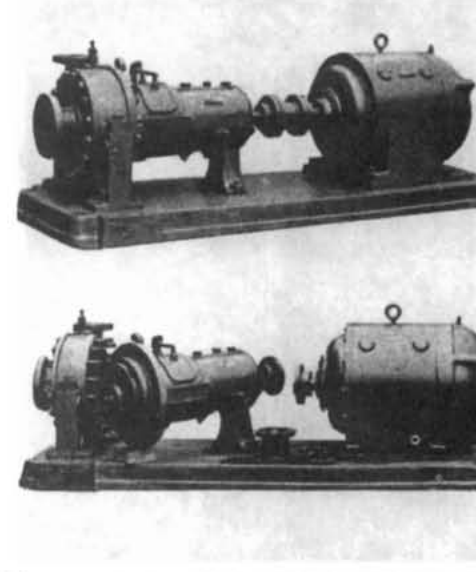




General purpose

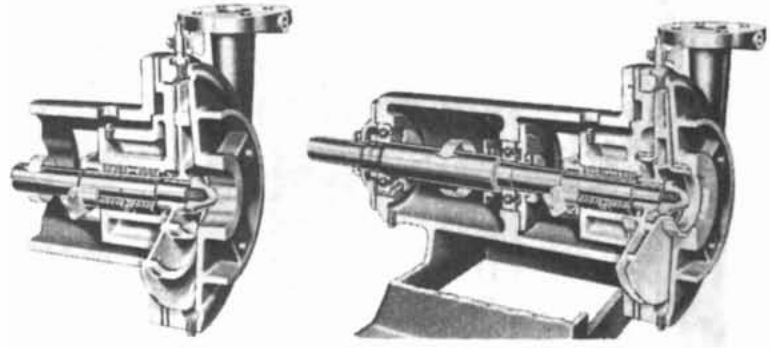
This term applies to all classes of pumps, but centrifugal designs in this category perhaps outnumber all others. Usual meaning of term is a pump to handle clear cool liquids at ambient or moderate temperatures. Often single-stage, these units may be split-case, and are standard-fitted pumps equally good for a number of services. Some handle liquids with solids.

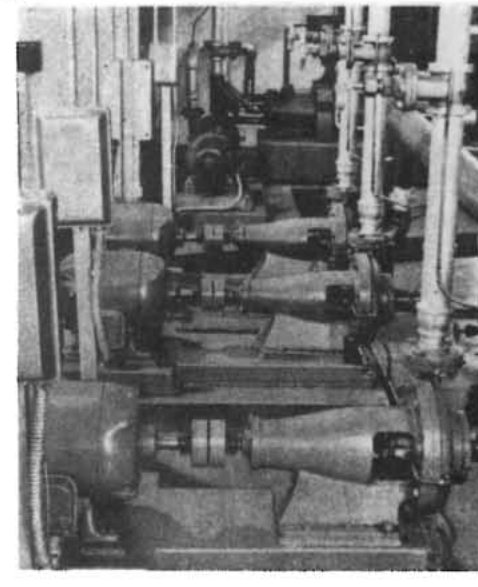




General process work

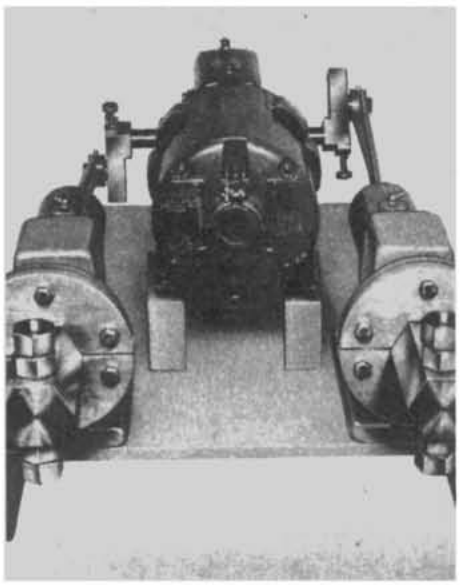
In recent years engineers have developed special process-pump designs featuring accessibility, good efficiency and long life. Some designs are available as part of a standard line whereas others are made up to suit the particular service conditions for a specific job. As these illustrations show, ease of maintenance is a prime consideration; complete disassembly is simple.

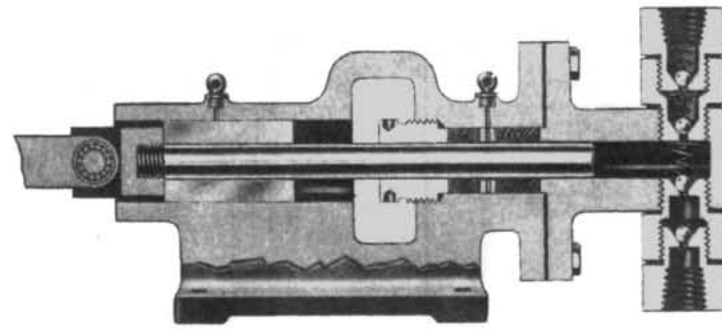




Chemical process

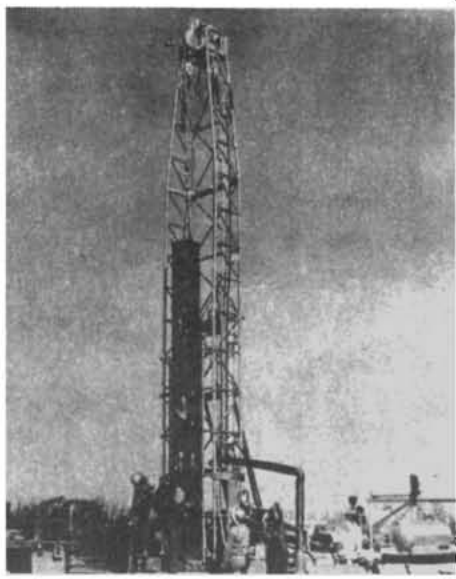
Outwardly resembling the general process pump, units designed for chemical service may differ markedly in materials, stuffing boxes, seals, etc. Usual aim is to produce a single pump line that comes as close as possible to being able to serve all process needs in the chemical industry. Usual units are horizontal, with radially split casings. They can handle a wide range of chemical liquids.

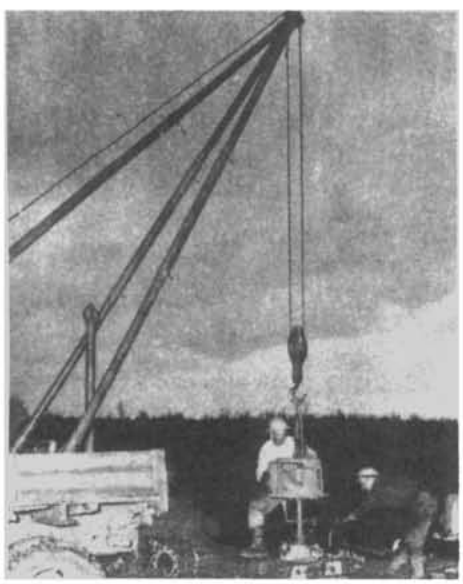


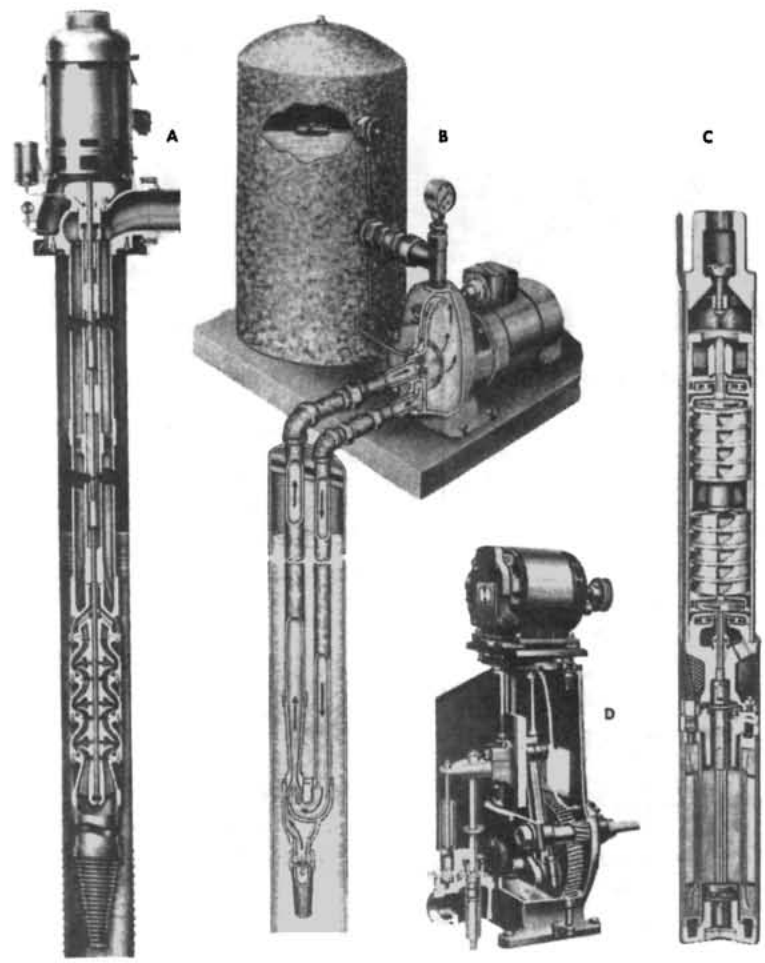


Chemical feed

Requiring easy adjustment of capacity, chemical-feed pumps are built in a large number of different designs. Unit shown has its reciprocating pumping elements arranged for accessibility. Suction and discharge valves are ball type.

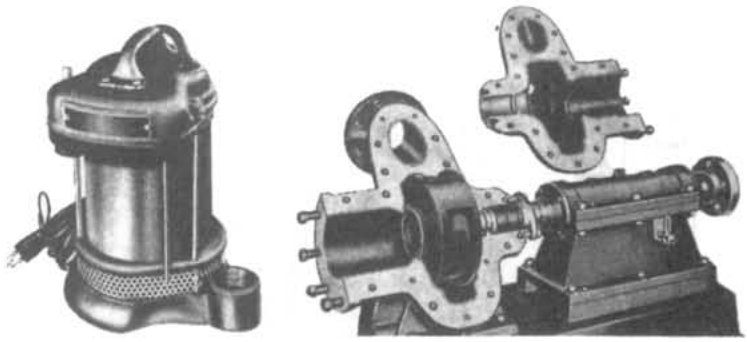






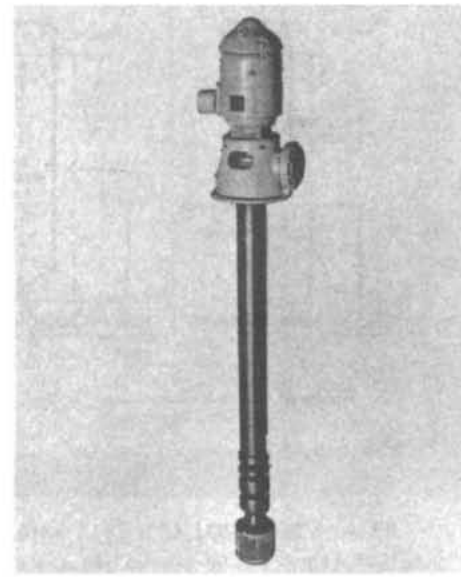
Well-water supply

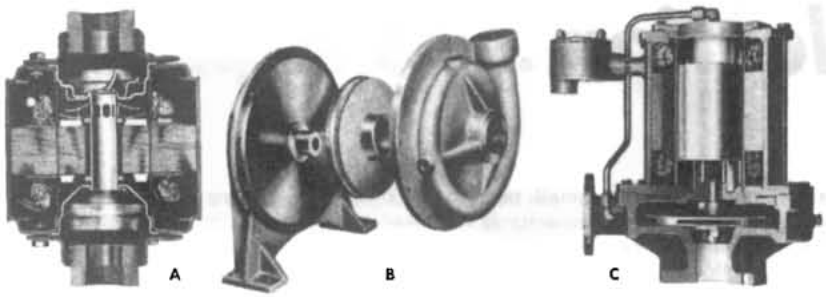
Water, like gold, is where you find it. Often this is deep in the earth. So we find many designs for this service. *Deepwell* pump, *A*, often called a *turbine* pump, is a multi-stage diffuser unit. *Jet pumps*, *B*, bypass a portion of their discharge to an ejector nozzle at the suction screen where it helps improve flow into pump. *Submersible*, *C*, has motor in well. *D* is *plunger* pump.



Sewage and sump

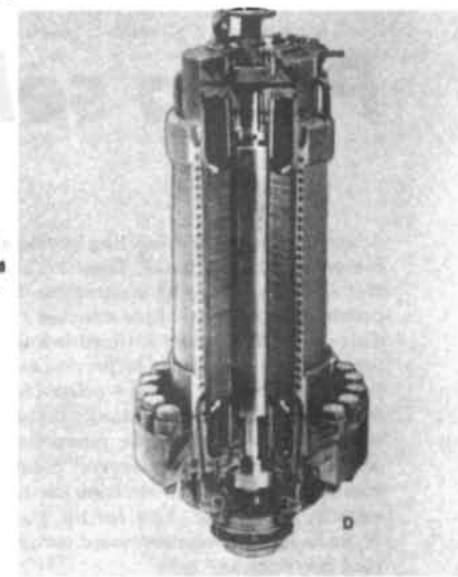
Centrifugal pumps for sewage usually have special non-clogging impellers and a casing that is easily opened for unit inspection, *above right*. Sump pumps, *left* and *extreme right*, may be portable or permanent, depending on needs of the installation. Impeller is almost always the non-clogging type to prevent solids from catching in it. Automatic control is practically universal.

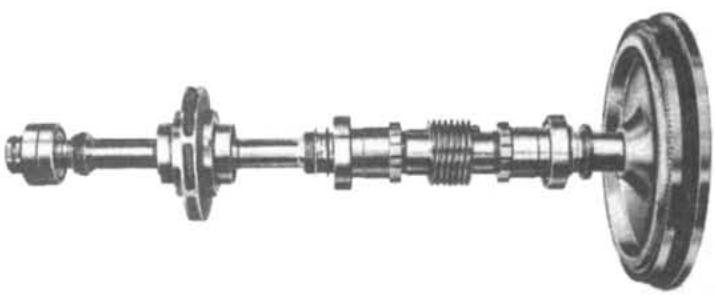




New and special services

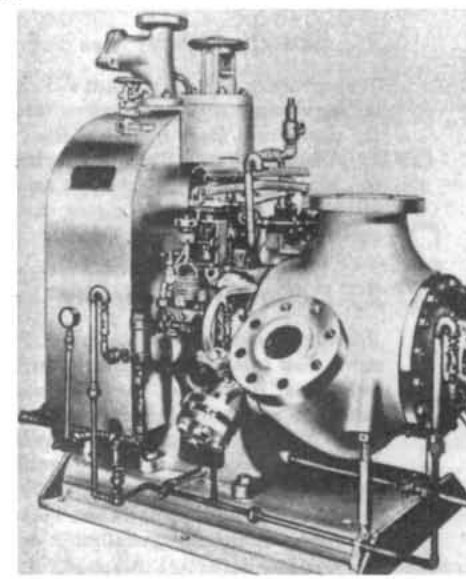
Developed in '30s for hot-water circulation, and later refined for chemical and nuclear-power jobs, canned pumps are now strongly bidding for industrial jobs where leak-free service and minimum maintenance are essential. Unit *A* is fractional hp, goes right in pipe. *B* has axial air-gap motor, is built in 10-hp and smaller sizes. *C* is chemical unit, *D* one for nuclear-energy service.



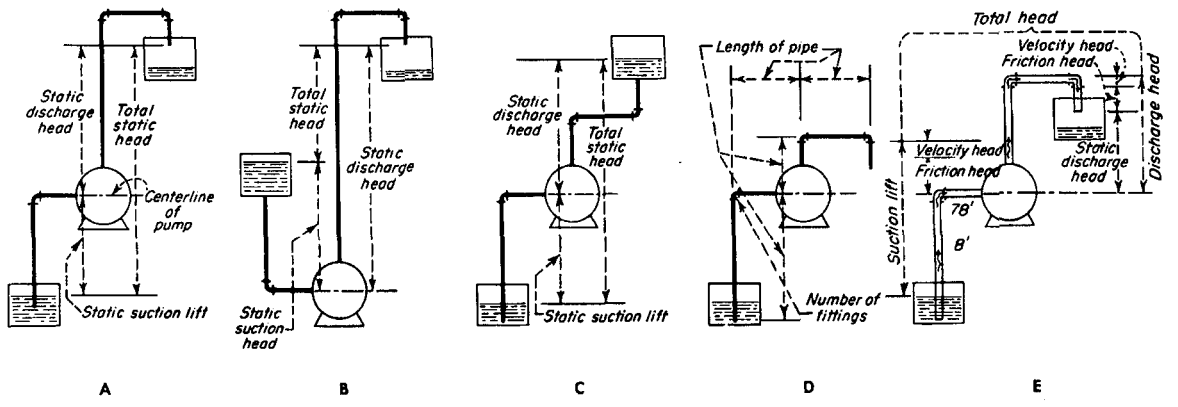


High-pressure services

Where quick starts, compact installation and steam drive are desirable, as in certain boiler-feed applications, petroleum refining, etc, the high-pressure turbine-driven type shown above has many uses. It consists of a single-stage impeller near one end of the shaft; at the other end is a velocity-staged turbine wheel. Single shaft produces a compact unit easy to install and operate.



Typical piping hookups for pumps serving industrial loads



Pump selection . . . 5 steps to

Selecting a pump is much like buying a hat—you have three major decisions to make. These are *size, type* and *best buy*. But of course choosing a pump can be a far more complex problem, especially where unusual or difficult liquid conditions are met. Steps outlined below have proven suitable for typical general-purpose, process and similar applications. Selection of other types — boiler-feed, condensate-return, hydraulic-system, etc. — usually involves analysis of factors not directly related to the pump itself. For example, you might have to compute several plant heat balances before you can make a firm decision on boiler-feed pump type, capacity, drive, etc., best for the existing conditions. Some of these factors were discussed earlier; others are too complex for coverage here.

1 Sketch layout (see diagrams above)

Trying to pick a pump without a sketch of the system layout is like a miner trying to work without his lamp. You're in the dark from start to finish. Base sketch on actual job, as planned. Show all piping, fittings, valves, equipment, etc. Mark length of pipe runs of sketch. Be sure to include all vertical lifts. Where piping is complex, an isometric sketch is often extremely helpful.

2 Determine capacity (see Table I)

Job conditions fix capacity required. For example, maximum steam flow from the exhaust of a turbine, along with steam conditions, determines the minimum amount of cooling water at a given temperature. Seasonal changes, safety factor desired, etc., influence actual capacity chosen. Where demand is unknown and must be estimated, Table I is a big help in indicating typical ranges to be expected. It does *not,* however, give exact values because there can be wide variations from one installation to another. Except for small pumps and those for metering and proportioning, capacity is expressed in gallons per minute (gpm).

3 Figure total head (see Tables II, III)

Diagrams above show various heads in typical pumping systems. Definitions, *facing page,* will help you understand the meanings of various terms. If a pump handles 500 gpm of water through 86 ft of 6-in. suction pipe, diagram above right, and there is one medium-radius elbow having a resistance equal to 14 ft of straight pipe, total equivalent length of suction pipe is 86 + 14 = 100 ft. Friction loss from Table II is 1.7 ft of water per 100 ft of pipe. Velocity head is almost 0.5 ft and static suction lift is 8 ft. Hence, suction lift is 8 + 1.7 + 0.5 = 10.2 ft. Discharge head is found in a similar way, using discharge pipe size, length of runs and fittings in the line. Total head is the sum of suction lift and discharge head. Where we have a static suction head, as in the second hookup from the left, we subtract suction head from discharge head to obtain the total head. Always have pump manufacturer check your head calculations. Then you'll be certain the pump is suitable.

4 Study liquid conditions

Up to this point we've determined but two requirements our pump must meet — head and capacity. Now we come to characteristics of the liquid and their effect on pump selection. Liquid heavier than water (specific gravity greater than 1) takes more horsepower to be moved from one point to another; lighter liquids require less power. Liquid temperature and vapor pressure fix the net positive suction head needed for satisfactory operation. Unless you are thoroughly experienced with this phase of pump selection, it is best to have the manufacturer check suction conditions. Viscosity of liquid affects horsepower, head and

DEFINITIONS

STATIC SUCTION LIFT is vertical distance, ft, from supply level to pump centerline; pump above supply.

STATIC SUCTION HEAD: same as static suction lift, but pump is below supply level.

STATIC DISCHARGE HEAD is vertical distance, ft, from pump centerline to point of free delivery.

TOTAL STATIC HEAD is vertical distance, ft, from supply level to discharge level.

FRICTION HEAD is pressure, in ft of liquid, needed to overcome resistance of pipe, fittings.

SUCTION LIFT is static suction head plus suction friction head and velocity head.

SUCTION HEAD is static suction head minus suction friction head and velocity head.

DISCHARGE HEAD is static discharge head plus discharge friction head and velocity head.

TOTAL HEAD is sum of suction lift and discharge head. Where there is suction head, total head is difference between discharge and suction heads.

NOTE: Some engineers use *dynamic suction lift, dynamic discharge head* and *total dynamic head* instead of terms above. While the word *dynamic* helps express idea of motion, ie, head when liquid is flowing, the simpler terms are favored.

I: TYPICAL WATER REQUIREMENTS

Usual buildings*			Cities and towns	
Fixture	Cold, gpm	Hot, gpm	Population	Total**, gpm
Water-closet flush valve	45	0	1000	800
Water-closet flush tank	10	0	2000	1200
Urinals, flush valve	30	0	3000	1500
Urinals, flush tank	10	0	4000	1700
Lavatories	3	3	5000	2000
Shower, 4-in. head	3	3	6000	2200
Shower, 6-in. and larger	6	6	8000	2700
Needle bath	30	30	9000	2900
Shampoo spray	1	1	10,000	3100
Baths, tub	5	5	20,000	5100
Kitchen sink	4	4	40,000	8700
Pantry sink, ordinary	2	2	50,000	11,000
Pantry sink, large bibb	6	6	60,000	13,000
Slop sinks	6	6	100,000	19,000
Wash trays	3	3	150,000	28,000
Laundry tray	6	6	180,000	33,000
Garden-hose bibb	10	0	200,000	37,000

*Approximate maximum flow from fixtures: to obtain maximum *probable* flow, multiply maximum possible flow by a usage factor based on previous experience.

**Total includes water for domestic supply and fire protection. Where city or town is predominantly industrial, a greater flow will probably be required.

II: PIPE FRICTION LOSS FOR WATER

(Wrought-iron or steel Schedule 40 pipe in good condition)

Dia, in.	Flow, gpm	Velocity, ft per sec	Velocity head, ft of water	Friction loss, ft of water per 100 ft pipe
2	50	4.78	0.355	4.67
2	100	9.56	1.42	17.4
2	150	14.3	3.20	38.0
2	200	19.1	5.68	66.3
2	300	28.7	12.8	146
4	200	5.04	0.395	2.27
4	300	7.56	0.888	4.89
4	500	12.6	2.47	13.0
4	1000	25.2	9.87	50.2
4	2000	50.4	39.5	196
6	200	2.22	0.0767	0.299
6	500	5.55	0.479	1.66
6	1000	11.1	1.92	6.17
6	2000	22.2	7.67	23.8
6	4000	44.4	30.7	93.1
8	500	3.21	0.160	0.424
8	1000	6.41	0.639	1.56
8	2000	12.8	2.56	5.86
8	4000	25.7	10.2	22.6
8	8000	51.3	40.9	88.6
10	1000	3.93	0.240	0.497
10	3000	11.8	2.16	4.00
10	5000	19.6	5.99	10.8
10	7500	29.5	13.5	24.0
10	10,000	39.3	24.0	42.2
12	2000	5.73	0.511	0.776
12	5000	14.3	3.19	4.47
12	10,000	28.7	12.8	17.4
12	15,000	43.0	28.7	38.4
12	20,000	57.3	51.1	68.1

III: RESISTANCE OF FITTINGS AND VALVES

(Length of straight pipe, ft, giving equivalent resistance)

Pipe size, in.	Std ell	Med-rad ell	Long-rad ell	45-deg ell	Tee	Gate valve, open	Globe valve, open	Swing check, open
1	2.7	2.3	1.7	1.3	5.8	0.6	27	6.7
2	5.5	4.6	3.5	2.5	11.0	1.2	57	13
3	8.1	6.8	5.1	3.8	17.0	1.7	85	20
4	11.0	9.1	7.0	5.0	22	2.3	110	27
5	14.0	12.0	8.9	6.1	27	2.9	140	33
6	16.0	14.0	11.0	7.7	33	3.5	160	40
8	21	18.0	14.0	10.0	43	4.5	220	53
10	26	22	17.0	13.0	56	5.7	290	67
12	32	26	20.0	15.0	66	6.7	340	80
14	36	31	23	17.0	76	8.0	390	93
16	42	35	27	19.0	87	9.0	430	107
18	46	40	30	21	100	9.2	500	120
20	52	43	34	23	110	2.0	560	134
24	63	53	40	28	140	14.0	680	160
36	94	79	60	43	200	20.0	1000	240

better results

capacity, as well as class of pump chosen. Here, again, your best bet is the manufacturer. Liquid pH influences pump materials, p 85, while solids affect mechanical construction.

5 Choose class and type

Studying the laycut, like trying on a hat, tells us what *size* (capacity and head) pump we need. This furnishes our first lead as to what class of pump is suitable. For example, where high-head small-capacity service is required, table p 77, shows that a reciprocating pump would probably be suitable. Reviewing the liquid characteristics furnishes another clue to class because exceptionally severe conditions may rule out one or another right at the start. Sound economics dictates choosing the pump that provides the lowest cost per gallon pumped over the useful life of the unit.

Operating factors deserving recognition when deciding on class include type of service (continuous or intermittent), running-speed preferences (high-speed pumps often cost less), future load expected and its effect on pump head, possibility of parallel or series hookup, and many others peculiar to a given job. These factors deserve as much study as head and capacity; they're just as important.

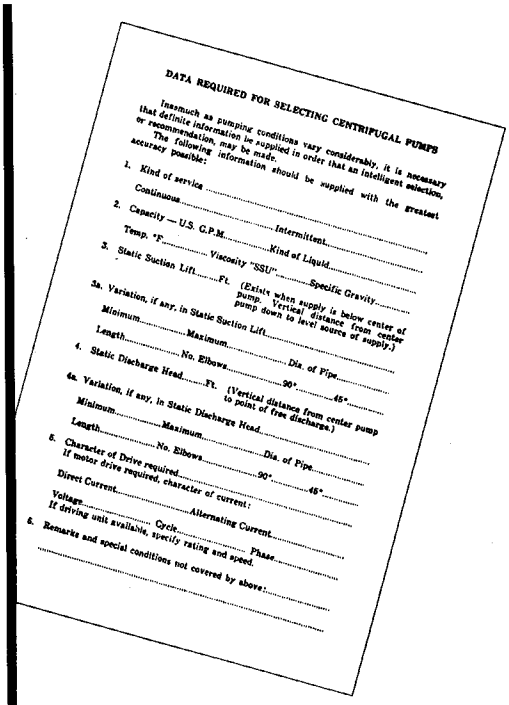
Once you know class and type you're ready to check these in a rating table, p 104, or a rating chart as on p 87. As you can see, the table lists pump capacity, head, horsepower, etc. Where required capacity and head, or both, falls between two tabulated values, it is usual practice to choose a pump to meet the next larger condition where this is not too far from the existing job conditions. Otherwise, another make or type of pump may have to be used.

One important fact to keep in mind is that many large pumps are custom-built for a given plant or application. Under these conditions the pump manufacturer performs most of the steps listed above, basing his design on information supplied by the engineer on the job.

Typical centrifugal-pump rating table

Size	Gpm	Total head, ft 10	15	20	25	30
2C	100			1000-.8	1060-1.0	1150-1.2
	150			1070-1.2	1150-1.5	1240-1.7
	200				1250-2.1	1360-2.4
3CS	150	750-.53	850-.78	950-1	1030-1.2	1100-1.5
	200		950-1.1	1010-1.4	1100-1.7	1170-2
	250			1170-1.9	1190-2.3	1260-2.6
	300					1400-3.5
3CL	200	690-.63	800-.95	910-1.3	1010-1.6	1110-2.05
	300	870-1.2	950-1.6	1000-1.9	1100-2.4	1170-2.8
	400			1200-3.1	1230-3.7	1290-4.1
	500					1490-5.8
4C	400	750-1.3	850-1.8	940-2.4	1040-3	1120-3.7
	600			1080-4	1170-4.6	1210-5.5
	800					1400-8.4
1¼D	25		617-.21	707-.03	778-.40	845-.51
	50		680-.37	760-.49	865-.63	900-.76
	75			856-.78	916-.94	980-1.1
	100					
	125					
	150					
2DL	150		820-.93	850-1.1	930-1.35	990-1.6
	200			970-1.8	1040-2.1	1080-2.3
	250					
	300					

Example: 1080-4 indicates pump speed is 1080 rpm; actual input required to operate pump is 4 hp.



DATA REQUIRED FOR SELECTING CENTRIFUGAL PUMPS

Inasmuch as pumping conditions vary considerably, it is necessary that definite information be supplied in order that an intelligent selection or recommendation may be made.
The following information should be supplied with the greatest accuracy possible:

1. Kind of service .....
Continuous ..... Intermittent .....
2. Capacity — U.S. G.P.M. ..... Kind of Liquid .....
Temp. °F ..... Viscosity "SSU" ..... Specific Gravity .....
3. Static Suction Lift ..... Ft. (Exists when supply is below center of pump. Vertical distance from center pump down to level source of supply.)
3a. Variation, if any, in Static Suction Lift.....
Minimum ..... Maximum ..... Dia. of Pipe .....
Length ..... No. Elbows ..... 90° ..... 45° .....
4. Static Discharge Head ..... Ft. (Vertical distance from center pump to point of free discharge.)
4a. Variation, if any, in Static Discharge Head.....
Minimum ..... Maximum .....
Length ..... No. Elbows ..... Dia. of Pipe .....
6. Character of Drive required ..... 90° ..... 45° .....
If motor drive required, character of current:
Direct Current ..... Alternating Current .....
Voltage ..... Cycle ..... Phase .....
If driving unit available, specify rating and speed.
6. Remarks and special conditions not covered by above:.....

Other considerations in choosing pumps

Our previous two pages outline usual steps in choosing a pump for typical industrial services. There are cases, however, where selection is better made by the pump builder.

Estimating data sheets, *above right,* are available from manufacturers to aid you in making a complete statement of conditions a new pump must meet. When sending such an estimate to a manufacturer it is wise to include a clear free-hand sketch of the installation.

While the sheet shown is for a centrifugal pump, forms for reciprocating and rotary estimates resemble this closely. Having the manufacturer select your pump insures getting the right unit, *provided* you supply the information he needs.

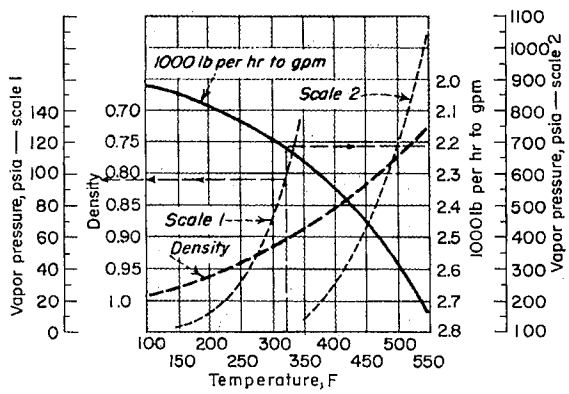
Net positive suction head is often listed on estimate sheets and must be entered to give a complete picture of pumping conditions. This term gives pressure available or required to force a given flow, gpm, into the impeller, cylinder or casing of a pump. For uniformity, npsh is stated as feet of liquid equivalent to required pressure in psi over and above vapor pressure of liquid at pumping temperature.

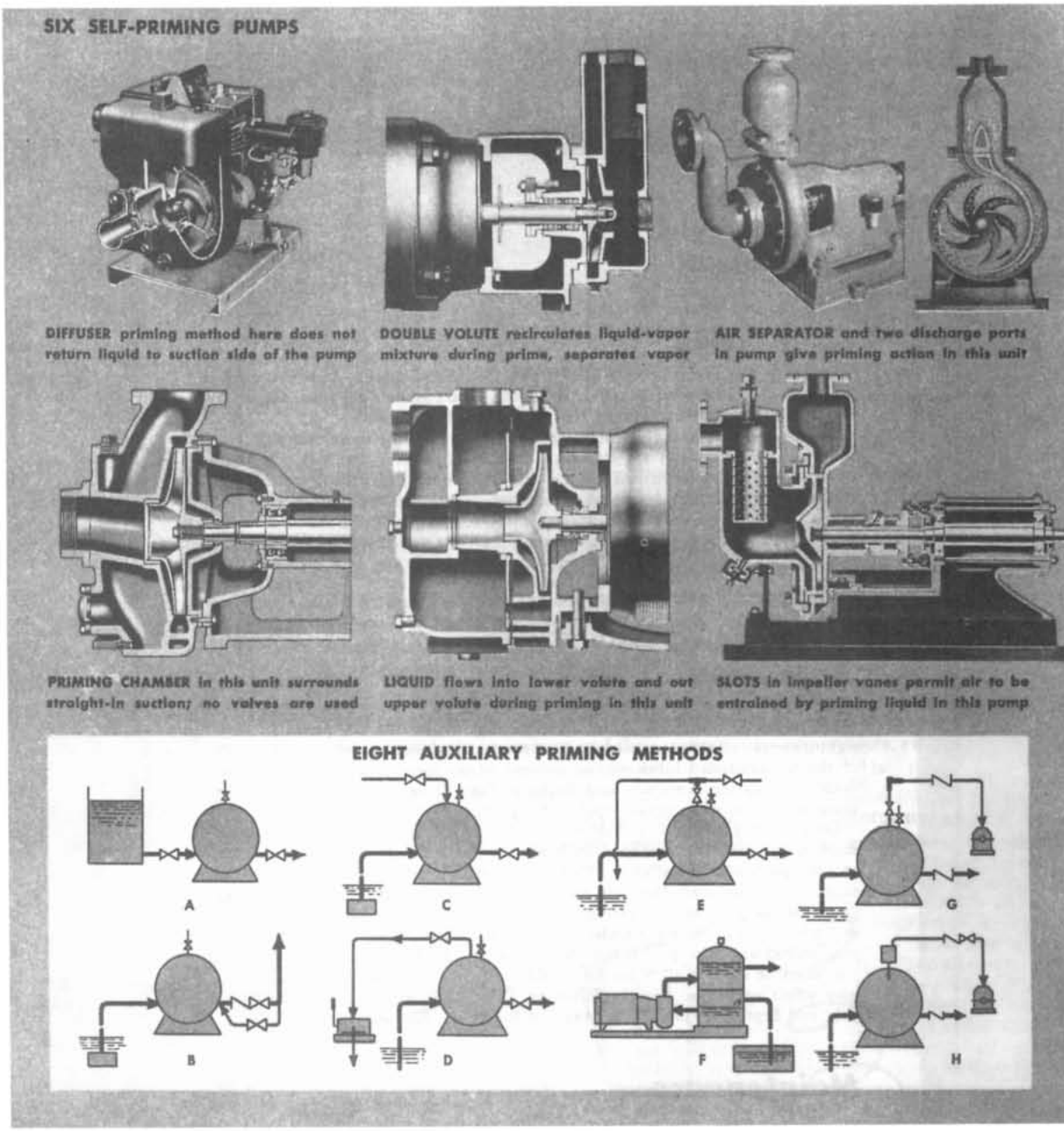
Every pump has its individual required npsh characteristics which the manufacturer can plot on a performance curve. Npsh at any point on the curve is head in feet of liquid pumped equivalent to pressure in psi required to force liquid into the pump. Values shown by pump manufacturer are based on tests and are regularly corrected to the centerline of the pump.

As engineer in charge of plant services you must locate the pump and design the suction piping so available npsh is equal to or greater than npsh required by pump. Curves, *right,* give vapor pressure of water at different temperatures. They also give conversion factors for changing flow from lb per hour to gpm. Both are useful in planning.

Pipe sizes for lines where flow demand is likely to change or resistance may increase over a period of years require careful study. If sized only on basis of today's demands or resistance, we may find that what was once an economical installation becomes a money-waster.

Complete Analysis. Though not all jobs warrant it, a piping system can be completely analyzed for present and future operations by using pump characteristic and system-head curves like those on p 86. But instead of plotting one system-head curve, a series, one for each operating condition, is plotted. Study of these will show just what we may expect from a given pump today, tomorrow, and five or more years from now. This is a job for the engineer in the plant and it deserves more attention than it usually receives.




SIX SELF-PRIMING PUMPS
DIFFUSER priming method here does not return liquid to suction side of the pump
DOUBLE VOLUTE recirculates liquid-vapor mixture during prime, separates vapor
AIR SEPARATOR and two discharge ports in pump give priming action in this unit
PRIMING CHAMBER in this unit surrounds straight-in suction; no valves are used
LIQUID flows into lower volute and out upper volute during priming in this unit
SLOTS in impeller vanes permit air to be entrained by priming liquid in this pump
EIGHT AUXILIARY PRIMING METHODS
A
B
C
D
E
F
G
H

Priming pumps

Positive-displacement pumps — reciprocating and rotary — are self-priming for total suction lifts to about 28 ft. when in good condition. But with long suction lines, high lifts or other abnormal conditions, they must be primed.

Centrifugal pumps are not self-priming; on a suction lift they must be primed. Either special self-priming units may be used or auxiliary priming equipment may be installed.

Illustrations at top of this page show six modern self-priming units. Designs vary from one maker to another, but a liquid reservoir of some type on the discharge is common. It holds priming liquid and serves as an air separator. Other designs have a liquid reservoir on both suction and discharge, liquid being circulated from discharge to suction on prime. Automatic valves or hydraulic action stop circulation after pump primes. Some pumps circulate liquid continuously.

Auxiliary equipment for pump priming includes ejectors, vacuum pumps, etc., used in hookups like those sketched.

With a flooded suction, *A*, open casing air-vent petcocks and then slowly open suction gate valve. Incoming liquid pushes air from casing. Bypass around discharge check valve, *B*, permits using liquid in discharge line. Foot valve, *C*, holds water in suction line, is augmented by auxiliary supply. Separate pump, *D*, draws air from casing for priming. Or an ejector, *E*, does same job. Priming tank, *F*, holds supply of liquid large enough to establish flow through pump on starting. Vacuum pumps, *G* and *H*, are manually and automatically controlled to prime the main pump.

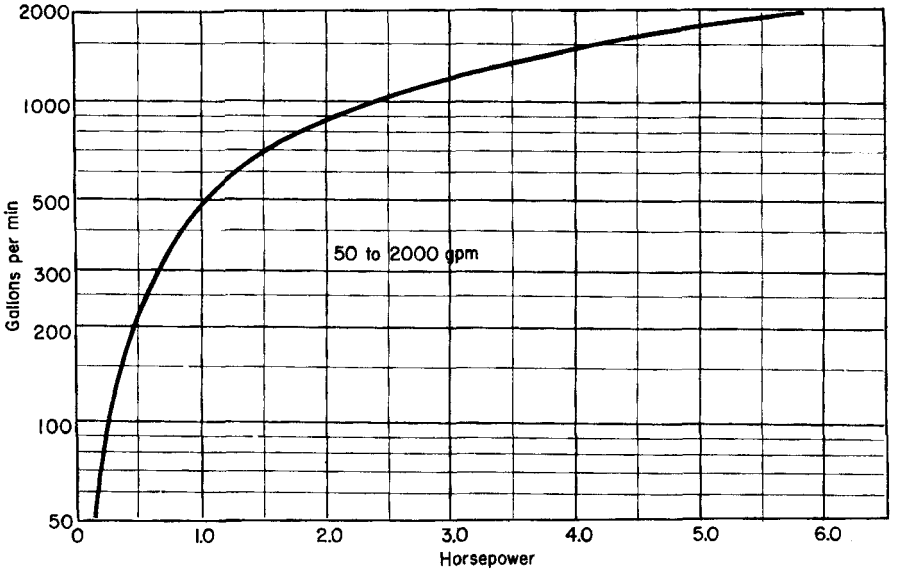
Find How Much Horsepower to Pipe Liquids

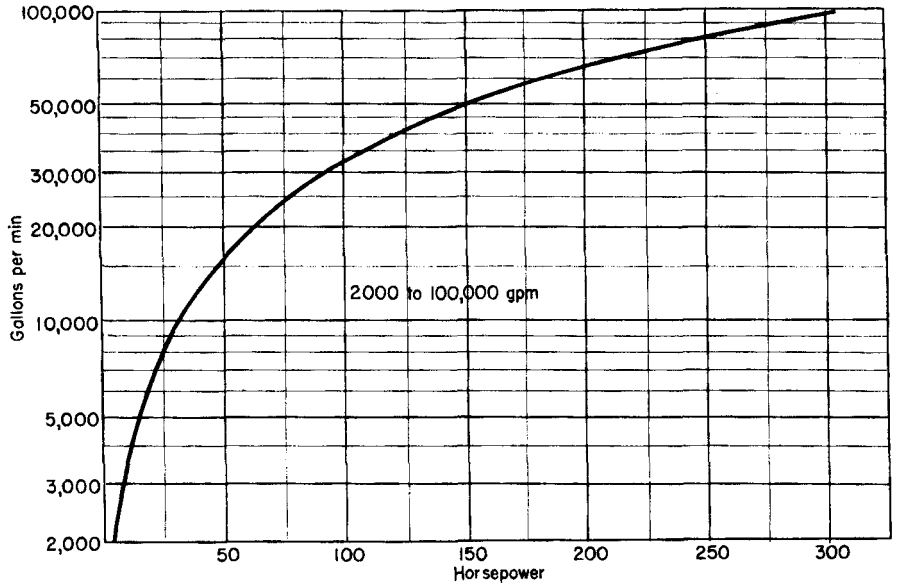
Charts give answers for flow from 50 to 100,000 gpm for pipe-roughness ratios of 0.02 to smooth.

Douglas C. Greenwood

The charts on these two pages will make it easier to design pumps and other equipment for handling liquid flowing in pipes.

First, it is often helpful to know the theoretical horsepower required to raise the liquid to various heads. This is obtained from the horsepower-gpm charts. They are plotted for a 10-ft head of water: For other heads, multiply hp by $H/10$ where H is the revised head; for other liquids, multiply by the corresponding specific gravity.





Hp-gpm Chart . . .

shows how much hp is required to pump water against a 10-ft head. Full-pipe flow is assumed.

SYMBOLS

G = flow rate, gpm
H_1 = head loss, ft
L = length of pipe, ft
P = pressure, psi
R = Reynold's number $= 0.0833\,Vd/\nu$
V = velocity, fps
d = pipe dia, in.
f = friction factor
w = fluid density, lb per cu ft
r = relative roughness of pipe $= \epsilon/d$
ϵ = effective height of roughness particle, in.
ν = kinematic viscosity, ft^2/sec

Next, for practical results friction losses must be accounted for. These vary and should be known for each individual case.

Much used in liquid-flow calculations is the Darcy formula

$$H_1 = f\frac{6LV^2}{d32.16}$$

which can be modified, if velocity is in gpm, to

$$H_1 = 0.0312f\frac{LG^2}{d^5}w$$

or for head loss in psi units

$$P = 0.000217f\frac{LG^2}{d^5}w$$

Practical values of f vary from about 0.01 to 0.06 depending on pipe smoothness and dia. For laminar flow, $f = 64.4/R$. The flow chart gives f for various values of R and pipe roughness. Values ϵ for various pipes are: 0.00006 in. for smooth drawn tubing; 0.0018 in. for wrought iron; 0.01 in. for cast iron. Curves for relative roughness values of 0.0005 to 0.01 are plotted. Most of these lie in the transition zone between laminar flow and complete turbulence.

Fluid-flow Chart . . .

gives friction for various pipe conditions and values of Reynold's Number.